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LAND USE AND WATER QUALITY CHARACTERIZATION OF BOEUF BASIN, LA

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Science

in

The Department of Environmental Sciences

by
Joseph W. LeBlanc
B.A., Louisiana State University, 2002
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ABSTRACT

The three primary goals of this project were to establish the ambient background of water quality in the Lake Boeuf basin in southeast Louisiana; establish land use patterns in the basin and the relation to water quality; and develop a preliminary plan to improve water quality through the use of best management practices and wetland assimilation. Urban and agricultural acreage borders the basin and runoff from these lands forces loadings of nutrients into the adjacent canals where they become channelized and ultimately exit the Boeuf Basin into Lac des Allemandes. From September 2007 until February 2008, water sampling occurred monthly at twelve discrete locations throughout the study area. These samples were tested for NO_x, PO_4, Si, NH_4, salinity, TSS, TN, and TP. Results of this data showed concentrations in the basin were not extraordinarily high. Sites located nearer to sugarcane acreages showed higher nutrient concentrations as compared to other sampling sites. Field data was compared to an existing dataset compiled by the Louisiana Department of Environmental Quality for use in establishing total maximum daily loads for the basin. Statistical analysis revealed significant decreases of PO4 and salinity concentrations from years 2000 through 2008. A yearly nutrient load estimate for the basin was established for NOx, NH4, TKN, TN, and TP. Using cited nutrient removal curves, it was determined that the available wetland acreage in Boeuf Basin could assimilate these loads achieving nearly 100% removal. Reductions in nutrient loads can be achieved by implementing best management practices in the adjacent agriculture. Other solutions include reducing direct flow from sugarcane field drainage ditches and diversion of this drainage through the wetlands allowing for assimilation.

CHAPTER 1: INTRODUCTION

1.1 Summary

Water pollution throughout the United States is a very serious problem. In Louisiana, a state with numerous waterbodies, water pollution poses an even larger threat. In the case of Boeuf basin, Lafourche Parish, LA, urban and agricultural development are the two leading causes of poor water quality. This thesis will define the ecological and land use conditions of the Boeuf Basin, as they exist, and act as a case study on ecological engineering of "impaired waters" in Louisiana via wetland assimilation. Through collection of this researchers' field data and comparison of this independently-collected data to existing Louisiana Department of Environmental Quality data, I propose to summarize conditions within the basin and provide recommendations for improvement.

1.2 Nonpoint Source Runoff

The three leading sources of estuary impairment are nutrients, metals, and organic enrichment (EPA 2002). A major reason for this impairment is the inability to control stormwater runoff. Rapid runoff from agricultural and developed areas during and after a weather event can result in delivery of nutrients and other pollutants into nearby waterways. This can be due to the nonporous surfaces on which precipitation falls, efficient drainage networks, or because the receiving surfaces have been saturated. In all cases, this runoff eventually flows into nearby water bodies carrying pollutants that degrade water quality.

Farming and fertilizer use has had the most recent influence on nutrient loading within the Mississippi River Basin; more so than the conversion of native vegetation to croplands and pastures (Turner and Rabalais 2003). Other factors include a reduction in agricultural crop diversity, high efficient drainage systems, loss of wetlands and riparian areas, and channelization of rivers and streams (Mitsch et al. 2001, Boody et al. 2005).

1.3 Regulation

The Clean Water Act of 1972 and its subsequent amendments were enacted with the purpose improving the quality of the nation's waters and required that all discharges of pollutants into a water of the United States be allowed only by obtaining a national pollutant discharge elimination system (NPDES) permit. The NPDES program required permits from all point-source discharges into surface waters. Given that stormwater was not considered a point-source, it was not regulated under the NPDES program. To remedy this, Phase I of the NPDES stormwater program was instituted in 1990. Phase I allowed for NPDES permitting of municipalities with populations in excess of 100,000 persons. In 1999, Phase II was instituted to allow permitting of smaller municipalities. These communities were now required to develop and employ a comprehensive stormwater management program (Frazer 2005).

Section 319 of the Clean Water Act (319 Program) was enacted in 1987. It created the Nonpoint Source Management Program. This program allowed the U.S. Environmental Protection Agency to fund grants to states for implementation of strategies to address nonpoint source pollution and required states to develop a Nonpoint Source Management Plan to manage nonpoint sources of (33 USC Sec. 1329). Nonpoint source pollution remains the most critical water quality problem in the United States and Louisiana. The Louisiana Department of Environmental Quality has been charged with setting all water quality standards for the state and assessing the quality of the state's waters based upon their designated uses. Section 303(d) of the Clean Water Act required states to compile lists of all impaired waters that did not meet set water quality requirements for these uses and for states to establish Total Maximum Daily Loads

(TMDLs) for these waters. The Lake Boeuf basin is on Louisiana’s list of impaired waters and a consent decree settlement has extended the deadline for finishing all Total Maximum Daily Loads (TMDLs) for Louisiana water bodies that are not meeting established water quality standards from 2007 until 2011. The deadlines for finishing TMDLs for Louisiana are outlined in Table 1.

Table 1: Deadlines for completing TMDLs for Louisiana

Basin	**State Target Completion Date**	**EPA Backstop Due Date**
Barataria (154)	March 31, 2004	March 31, 2005
Terrebonne (369)	March 31, 2007	March 31, 2008
Sabine (10)	March 31, 2007	March 31, 2008
Red (174)	March 31, 2007	March 31, 2008
Pearl (42)	March 31, 2008	March 31, 2009
Atchafalaya (29)*	March 31, 2009	March 31, 2010
Mississippi (64)*	March 31, 2010	March 31, 2011

* Water body/pollutant combinations listed for “Toxic Pollutants” within the Atchafalaya, Pontchartrain, and Mississippi basins will be addressed within the first two years following the date work is initiated in each such basin. “Toxic Pollutants” are defined as those pollutants listed in 40 C.F.R. § 401.15. Water body/pollutant combinations generically listed under descriptions that may include Toxic Pollutants, for example, including but not limited to, those listed for “metals”, “priority organics”, or “priority inorganics”, will be evaluated to establish the individual pollutant(s) of concern within the generic description, and treated as Toxic Pollutants only to the extent that the individual pollutants of concern fall within the definition of Toxic Pollutants provided above.(State of Louisiana, 2002)

The U.S. Department of Agriculture has implemented two conservation programs; the Conservation Reserve Program (CRP) and Conservation Reserve Enhancement Program (CREP). CRP provides technical and monetary assistance to agricultural landowners to deal with natural resource concerns on their lands. CRP promotes the use of best management practices to aid in environmentally effective management of these lands. Like the CRP, CREP is another voluntary program for landowners. The program consists of a land retirement program intended to protect environmentally susceptible lands from further degradation (www.nrcs.usda.gov).

1.4 Urban and Agricultural Runoff

High concentrations of nutrients in any water body can lead to eutrophic conditions that result in algae blooms, low dissolved oxygen, and fish kills (Elsorbagy et al. 2005). The presence of nutrients and pollutants in water basins is consistently tied to agricultural and urban land use in and around watersheds (USGS 1999). Urbanization has led to increased runoff and the degradation of adjacent ecosystems. Research has shown that stream channel erosion only exacerbates the problem by causing nearly 66% of long-term sediment yield in urban watersheds (Trimble 1997). This trend has brought about the need for improved landscape management (Paul and Meyer 2001).

In the case of Lake Boeuf, nutrient loading is the result of urban runoff from the city of Thibodaux and agricultural runoff from nearby sugarcane fields. The total maximum daily load (TMDL) report for the basin lists impairment due to nutrients and organic enrichment/low dissolved oxygen. In order to obtain the recommended standard for this basin, man-made nonpoint sources need to be reduced 100% in summer and 92% in winter. Natural nonpoint sources need to be reduced 37% in the summer (FTN Associates 2004).

In order to effectively manage a watershed, three goals need to be met: (1) rehabilitation of altered or abused watersheds, (2) protection for sensitive watersheds from activities that might lead to a need for rehabilitative measures, and (3) enhancement of the water resource characteristics by manipulating some of the watershed features (Elshorbagy et al. 2005).

1.5 Sugarcane and Water Quality

It is widely understood that sugarcane harvesting operations can lead to adverse water quality conditions. Fertilizers and pesticides are applied to sugarcane to increase harvest production, but due to runoff find their way into surrounding water bodies. Leaching of nitrogen and phosphorous from agricultural soils has been associated with higher nutrient concentrations in nearby water bodies (Chambers et al. 2006). In a study on sediment particle size and water quality, it was determined that nearly all TP and TN in stormwater attach to sediments ranging from 11 to 150 μm. Therefore any strategy to reduce TP and TN pollution due to sediment runoff needs to account for sediment sizes as small as 11 μm (Vaze and Chiew 2004).

1.6 Best Management Practices

In order to combat agricultural runoff, land managers must implement best management practices. In a study on sugarcane cultivation and the influence on water quality in Louisiana, it was determined that several practices can be beneficial in preserving and improving water quality of receiving basins (Southwick et al 2001). These include the use of evolving sugarcane varieties, better management of crop residue (burn vs. no-burn), use of filter strips along drainage ditches, and utilization of water settling areas that provide for sedimentation and the reuse of surface runoff. Additionally, NRCS recommends use of cover crops to anchor soils during non growing seasons, employment of conservation tillage, installation of tailwater drop structures, and land leveling to optimize furrow slopes. These practices are more prone to success when used concurrently (NRCS 1994).

Rice is a popular cover crop employed by Louisiana crawfish farmers. When applied to other agricultural fields, it was determined that rice, while not the most effective method, did reduce excess nitrogen and phosphorous levels from agricultural runoff (Moore, et al. 2007). In another study, nitrate losses from agricultural fields could be decreased by as much 90% when grass and alfalfa were employed to replace corn and soybeans as cover crops (Mitsch et al. 2001).

Research suggests that only a third of all water used for agriculture is used to grow useful plants (Wallace and Batchelor 1997). Although irrigation management is a useful practice in reducing agricultural runoff, Louisiana growers rarely have a need for irrigation of their crop. This is due to the large amount of rain that Louisiana receives each year; 152 cm. (LSU Ag Center 2000). Research on the success of best management incentive programs concluded that agricultural land managers were more prone to implement best management practices through the employment of educational programs that highlight benefits of adoption. However, educational programs are less likely to succeed when recommended practices require lofty financial obligations (Feather and Cooper 1995).

In 2003, it was observed that Louisiana sugarcane producers adopted best management practices at the following rates: use of cover crops 31%; use of filter strips 37%; fertilizer injection 15%; calibration of spray equipment 41%. Major reasons for non-adoption were cost and uncertainty in applicability. In spite of these low adoption rates, it was recommended that educational programs continue to be used to encourage use of best management practices (Zhong 2003). A complete list of best management practices for water runoff management is provided in Table 2 (NRCS Planning and Design Manual 1994).

1.7 Ecological Engineering and Wetland Assimilation

Although implementation of agricultural best management practices proves beneficial for improving water quality, employment of strategies that utilize principals of ecological engineering can also provide solutions to runoff management and improving water quality.

Table 2: Best Management Practices for Runoff Management (NRCS Planning and Design Manual, 1994)

Construction Site Impact Reduction (temporary practices)	**Erosion Control**	**Water Quality Treatment and Constituent Entrapment**
Brush Barrier	Channel Vegetation	Basic Biofiltration Swale
Construction Entrance/Exit	Check Dam	Biorentention System
Construction Sequences	Concrete Block Revetment	Combined Infiltration/Detention Basin
Silt Fence (Filter Fence)	Critical Area Planting	Compost Filter System
Storm Drain Inlet Protection	Erosion Control Blanket	Constructed Wetland
Straw Bale Barrier	Gabions/Gabion Revetment	Detention Devices for Dry/Wet Ponds
Temporary Seeding	Grade Stabilization Structure	Dry Extended Detention Ponds
Topsoiling	Grassed Waterway	Dry Swale
	Lined Waterway	Filter Strips
Source Reduction	Low Wall/Slope Face Plantings	Median Strip Infiltration Trench
	Mulching, Netting, and Matting	Montgomery County Water Quality Inlet
Animal Waste Collection	Native Revegetation	Off-Line Infiltration Basin
Bedding	Sheet Flow Dispersion	Oil/Grit Separator
Chiseling	Sodding	Oil/Water Separators
Cisterns for Water Harvesting	Stone Revetment	Organic Sand Filter
Concrete Grid	Terracing	Peat Sand Filter
Curb Elimination	Water Bar	Perimeter Sand Filter
Debris Removal		Pocket Sand Filter
Drain Blockers	**Water Volume Management**	Reversed Elevations System for Parking Lots and Planting Areas
Education Programs		Riparian Forest Buffer
Exposure Reduction	Detention Basin	Roadway Landscape Treatment System
Green Roofs	Dispersion Trench	Rovkville Water Quality Inlet
Landscape Management Controls	Diversion Channel	Sediment Basin
Minimization of Pollutants	Diversion Structure (Flow Splitter)	Side-by-Side Infiltration Basin
Parking Lot and Street Cleaning	Dry Well	Surface Sand Filter
Protecting Storm Drains from Haz. Waste	Exfiltration/Infiltration	Underground Sand Filter
Stormwater Catch Basin Insert	Infiltration Trench	Underground Trench with Oil/Grit Chamber
	Isolation/Diversion Structure	Under-the-Swale Infiltration Trench
	Off-Line Infiltration System Design	Water Quality Volume Storage Tank
	Parking Lot Perimeter Infiltration Trench	Wet Biofiltration Swale
	Parking Lot Storage	Wet Pond Design
	Small Infiltration Basin	Wet Swale
	Storm Water Retention Pond	
	Wetland Animal Habitat Design	

Mitsch and Jorgenson defined ecological engineering as “the design of sustainable ecosystems that integrate human society with its natural environment for the benefit of both” (2004). Using wetlands to assimilate polluted waters is a prime example of ecological engineering. Wetlands can remove nitrogen and phosphorus in runoff (Day et al. 2003) and research shows that natural swamps can also greatly aid in removal of total Kjeldahl nitrogen (TKN) and total phosphorous (TP) from tertiary wastewater. Introduction of wastewater can shift nutrients from organic forms to inorganic and encourage nutrient cycling in the swamp. Other research confirmed that the reduction of TKN and TP in Pointe-au-Chene Swamp (southwest of Thibodaux) were 69% and 66%, respectively (Zhang et al. 2000).

The use of wetlands to reduce nutrient concentrations is also beneficial to the receiving wetlands. Studies have shown that the nutrient rich waters can lead to increased surface elevation, vertical accretion of vegetation, and reduced subsidence within the wetland (Mitsch and Jorgensen, Day et al. 2004, Lane et al. 2006).

1.8 Objectives

Lake Boeuf is a freshwater lake located in Lafourche Parish, Louisiana approximately eight miles east of Thibodaux. The Lake itself is only a portion of the sub-basin that includes a network of bayous and streams that drain part of Thibodaux and surrounding agricultural fields. Runoff from these areas has had a harmful affect on the water quality within the basin and no plan currently exists to remedy the situation. The basin is currently listed as impaired for dissolved oxygen and by utilizing the concept of ecological engineering, this thesis will attempt to:

(1) establish the ambient background of water quality in the Lake Boeuf basin,

(2) describe land use in the basin and the relation to water quality, and

(3) develop a preliminary plan to improve water quality through the use of best management practices and wetland assimilation .

CHAPTER 2: MATERIALS AND METHODS

2.1 Study Area

The study area is located in a deltaic landscape that includes freshwater wetlands, agriculture, and developed areas (Figure 1). The area is bounded on the west by LA-20, south by Bayou Lafourche, and north and east by LA-307. Bayou Lafourche and the two highways are natural ridges that form the basin boundaries encompassing an area approximately 312km^2. The area contains five primary water bodies including Lake Boeuf, Halpin Canal, Grand Bayou, Theriot Canal, and Bayou Boeuf. Water enters the project area from the west via Grand Bayou and south by means of Theriot Canal eventually draining north into Lac Des Allemandes. Although Theriot Canal is connected to Bayou Lafourche, flow exchange is restricted by a gated structure that remains closed during low flow periods. The primary water exchange on Theriot Canal occurs when agricultural drainage canals carry runoff from sugarcane fields causing nutrient rich waters to be channelized.

Like the majority of south Louisiana marshes, Boeuf basin struggles with the effects of subsidence. This, combined with nearly continuous flooding in the basin provide for a lack of regeneration in the swamp. Lake Boeuf is characterized by freshwater floating marshes (*Panicum hemitomon)* and these marshes, along with other vegetation, make the lake nearly non -navigable in late summer and fall. The marsh vegetation in Lake Boeuf is dominated by cattail (*Typha domingensis*), water hyacinth (*Eichhornia crassipes*), alligator weed (*Alternathera philoxeroides*), and giant cutgrass (*Zizaniopsis miliacea*). Coontail (*Ceratophyllum demersum*) was the only sub aquatic vegetation observed. Bald cypress (*Taxodium distichum*), and red swamp maple (*Acer rubrum*) line the banks of the major bayous. Sasser (1994) investigated floating marshes in Louisiana, and found that over 65% of the live biomass of floating marshes

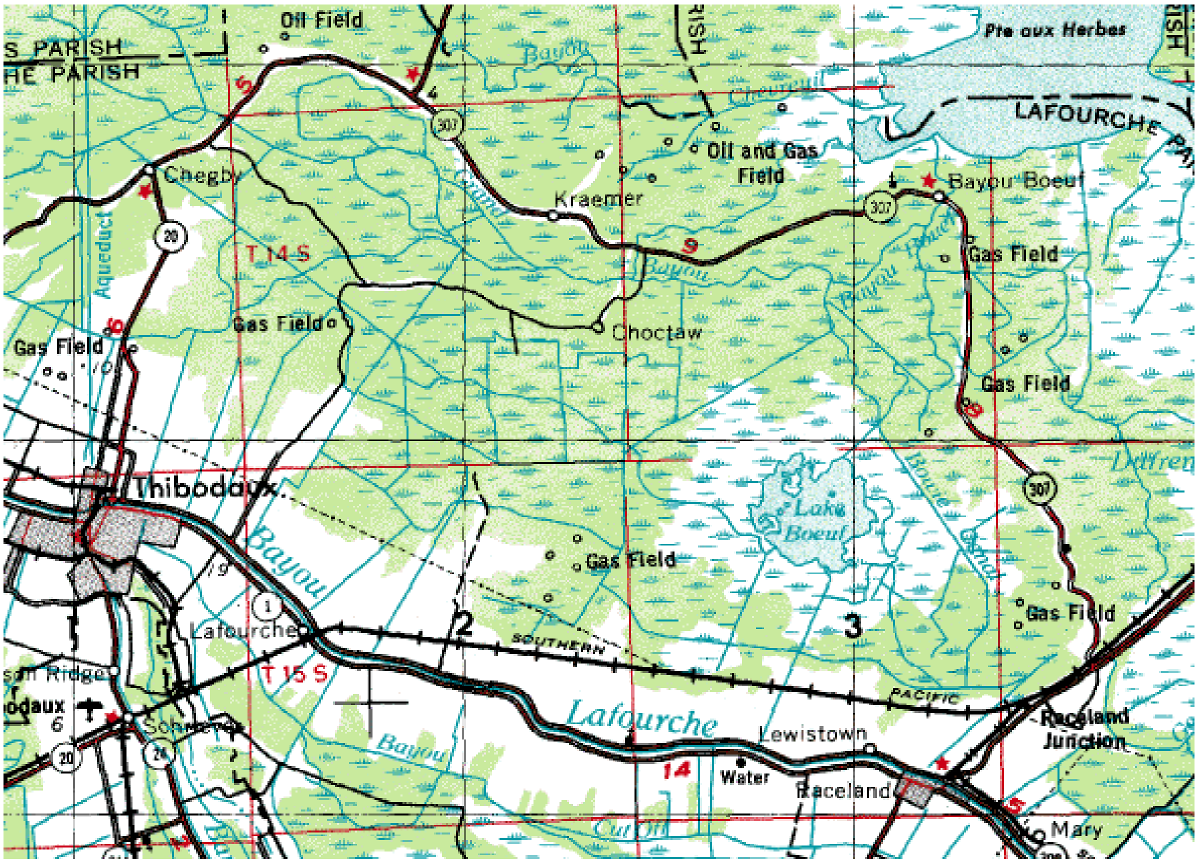

Figure 1: Lake Boeuf sub-basin

in Lake Boeuf was made up of *Panicum hemitomon* and that marsh adjacent to the lake had decreased by only 4% from 1945 to 1992. This is contrary to Nelson et al. (2002) who documented land cover changes in the upper Barataria Basin from 1972 to 1992 and reported a 38% decrease in bottomland hardwood forest and a 21% increase in wetland area. Sasser and Gosselink (1984) determined that productivity of the floating marsh in Lake Boeuf was approximately 1700 g dry wt/m2 annually. Connor and Day (1991) established that freshwater floating marsh in the area remained floating throughout the year, provided water levels were high. This steady floating was attributed to shallow substrate and poor mineral sediment. Sasser et al. (1991) suggested that the rise and fall of floating marshes due to water levels had an affect on nutrient budgets within the system; higher water levels dilute nutrient concentrations under the mat, while lower water levels force nutrients out from beneath the mat.

2.2 Water Budget

A water budget shows how precipitation and evapotranspiration interact to generate either a surplus or deficit of water over the year, and thus the potential to generate runoff. Figure 2 shows a water budget for Thibodaux (Rybczyk 1997). The components of the water budget include surface water inflows/outflows and evaporation and precipitation. The average annual evapotranspiration is 110.5 cm and is relatively constant from year to year. Evapotranspiration varies over the year due to seasonal changes in temperature. Seasonal and annual variations in rainfall give rise to variability in the water surplus/deficit (P-PE). On average, there is a surplus of 22.1 inches in this area. Because of the seasonality of evapotranspiration, most winter precipitation runs off but much of summer precipitation is evaporated. Heavy summer rainfalls can lead to runoff, but on average the highest runoff is in the cooler months. The management implications of this are that the cooler months are when most nutrients enter the waterways of the basin and thus this is the time when water quality problems must be addressed.

2.3 Land Use

The project area is within the Barataria Basin and this basin was historically fed by fresh water from the Mississippi River and Bayou Lafourche and minor distributaries within the basin such as those off highways 20 and 307. Due to construction of levees along the Mississippi River and the closing of Bayou Lafourche at the Mississippi River this fresh water input decreased. The project area, unlike the majority of the Barataria Basin, is a freshwater wetland area although it receives occasional low level inputs of salinity at its southern end.
Due to the availability of fresh water and high elevations, the natural levees were settled in the 18th and 19th centuries and agricultural activity thrived (BTNEP, 1995). Oil and gas exploration in Louisiana's coastal wetlands began in the late 1920's and contributed to wetland loss (Day et al. 2007).

There are a number of oil and gas canals in the study area. Ko and Day (2004) outlined multiple vulnerabilities of wetlands to oil and gas activities (Table 3). Acreages and land use types of the project area are outlined in Table 4 and Figure 3. Forested wetlands and fresh marsh comprise 67% of land use with agriculture making up over 20%.

2.4 Sampling

In order to characterize the current water quality status of the area, water samples were taken on September 14, 2007, October 12, 2007, November 16, 2007, December 14, 2007, January 18, 2008, and February 29, 2008. This time period for sampling spans climatic conditions from hot summer with high evaporation to cooler winter conditions with a high freshwater surplus and runoff from the agricultural fields. These samples were taken at twelve

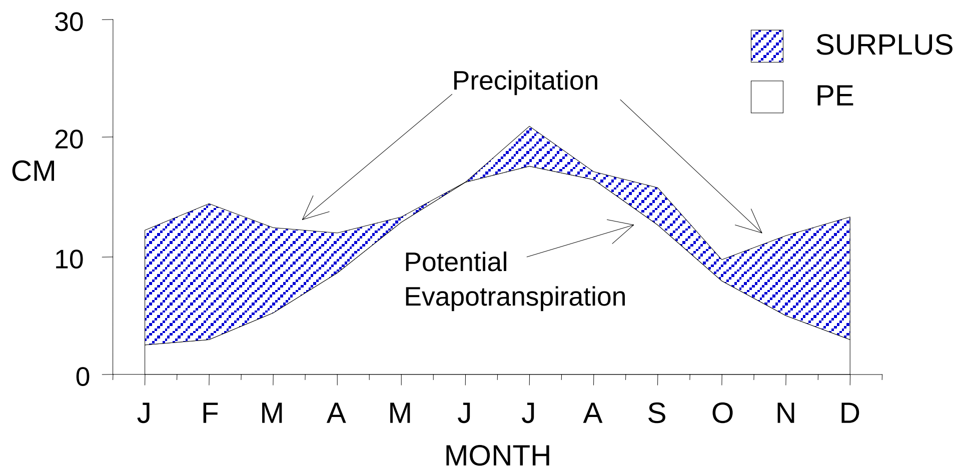

Figure 2: Mean water budget values for Thibodaux, LA. 1931-1988 (Rybczyk 1997).

Table 3: Multiple Impacts of Energy Development inside Wetlands (Ko and Day 2004)

Multiple Impacts of Energy Development inside Wetlands

Stage	Short-term impacts	Long-term impacts
Exploration	Changes in marsh surface elevation	Changes in surface hydrology and drainage
	Breaks in natural hydrological barriers	Saltwater intrusion
	Noise and commotion during exploration	Changes in plant growth, organic matter accumulation, and sediment distribution
	Immediate loss of marsh vegetation	
	Destruction of biota	
	Changed habitat	
	New migration pattern of aquatic organisms inside marsh	
Access to site	Direct conversion to open water	Increased wave action
	Direct conversion to spoil bank habitat	Changed water circulation and turnover; stagnant water
	Return of nutrients and toxins to marsh	Dredged canal deeper than natural channel
	Noise and commotion during construction	Intercepted freshwater flow
	Immediate loss of marsh/shallow water habitat	Saltwater intrusion
	Changes in soil/water chemistry	Increased drainage of marsh
	Destruction of biota	Changes in surface hydrology and drainage
	Potential for interrupting fish spawning and feeding	Changes in sediment distribution
	Potential negative impact on plant growth	Changes in interaction of surface/subsurface hydrology and sediment distribution
	Potential for disturbing avifauna nesting by noise	
Drilling	Reduction in water quality	Alteration of surface hydrology and drainage
	Return of nutrients and toxins to surroundings	Changes in subsurface hydrology and drainage
	Inhibition of rainfall penetration	Changes in sediment distribution
	Noise and commotion during construction	Saltwater intrusion
	Increase in suspended solids	
	Changes in soil/water chemistry	Increased sediment release from discharges
	Changes in plant growth	Anoxia
	Destruction of biota	Loss of marsh habitat
	Potential for interrupting fish spawning and feeding	Altered soil/water chemistry
	Potential for disturbing avifauna nesting by noise	Possible negative influence on aquatic/benthic organisms
		Changes in mineral accretion and soil nutrition
Production	Noise and commotion during construction	Noise of processing facilities
	Flowlines in the marsh	Changes in surface hydrology and drainage
	Pit construction; toxins to surroundings	Changes in subsurface hydrology and drainage
	Changes in marsh elevation	Saltwater intrusion
	Reduction in water quality	More saltwater species
	Saltwater disposal	Anoxia
	Oil spills	Increased localized subsidence
	Destruction of biota	Loss of marsh habitat
	Potential for interrupting fish spawning and feeding	Altered soil/water chemistry
	Potential for disturbing avifauna nesting by noise	Possible negative influence on aquatic/benthic organisms
Pipeline building	Direct conversion to open water	Changes in surface hydrology
	Increased turbidity	Bank erosion
	Loss of forested wetlands	Compacted marsh surface
	Noise and commotion during construction	Direct habitat conversion
	Increased susceptibility to storm damage	Indirect wetland loss

*Table Continued on next page

Stage	Short-term impacts	Long-term impacts
	Formation of open water ponds	Changes in forest succession
	Disruption of natural surface drainage	Changes in plant species, composition, diversity, and percentage cover
	Release of nutrients and toxins	Shoreline bank stability
	Soil oxidation	
	Changes in plant species, composition, diversity, and percentage cover	
	Nesting disturbance	
	Changed habitat	
	Disturbance of fish spawning and feeding	
	Impacts on plant growth	
	Destruction/Disturbance of benthos	
Spill control	Interruption of tidal cycle	Loss of marsh habitat
	Direct conversion of marsh to open water	Injury to birds and wildlife
	Trampling of vegetation	
	Immediate loss of marsh habitat	
	Temporary interruption of aquatic organism migration and flux of matter	
	Injury to birds and wildlife	
	Disruption of avifauna nesting	
Cleanup	Potential disruption of substrate	Loss of marsh habitat
	Removal of vegetation	Injury to birds and wildlife
	Immediate loss of marsh habitat	
	Decrease in biological production	
	Destruction of vegetation and benthic organisms	
	Potential negative impact on plant growth	
	Potential injury to wildlife	

Table 4: 2005 Land Use/Land Cover for Boeuf Basin (Broad et al. 2006)

Land Use (020102/03)	Acres	Percent
Forested Wetland	44,058.86	57.1%
Deciduous Forest	4,853.47	6.3%
Agriculture – Sugarcane	7,657.68	9.9%
Agriculture - Bare Field	2,798.98	3.6%
Agriculture – Pasture	5,324.20	6.9%
Shrub / Scrub	1,278.77	1.7%
Water	1,699.42	2.2%
Urban or Built-up Land	1,758.10	2.3%
Marsh – Fresh	7,660.67	9.9%
Unclassified	7.66	0.0%

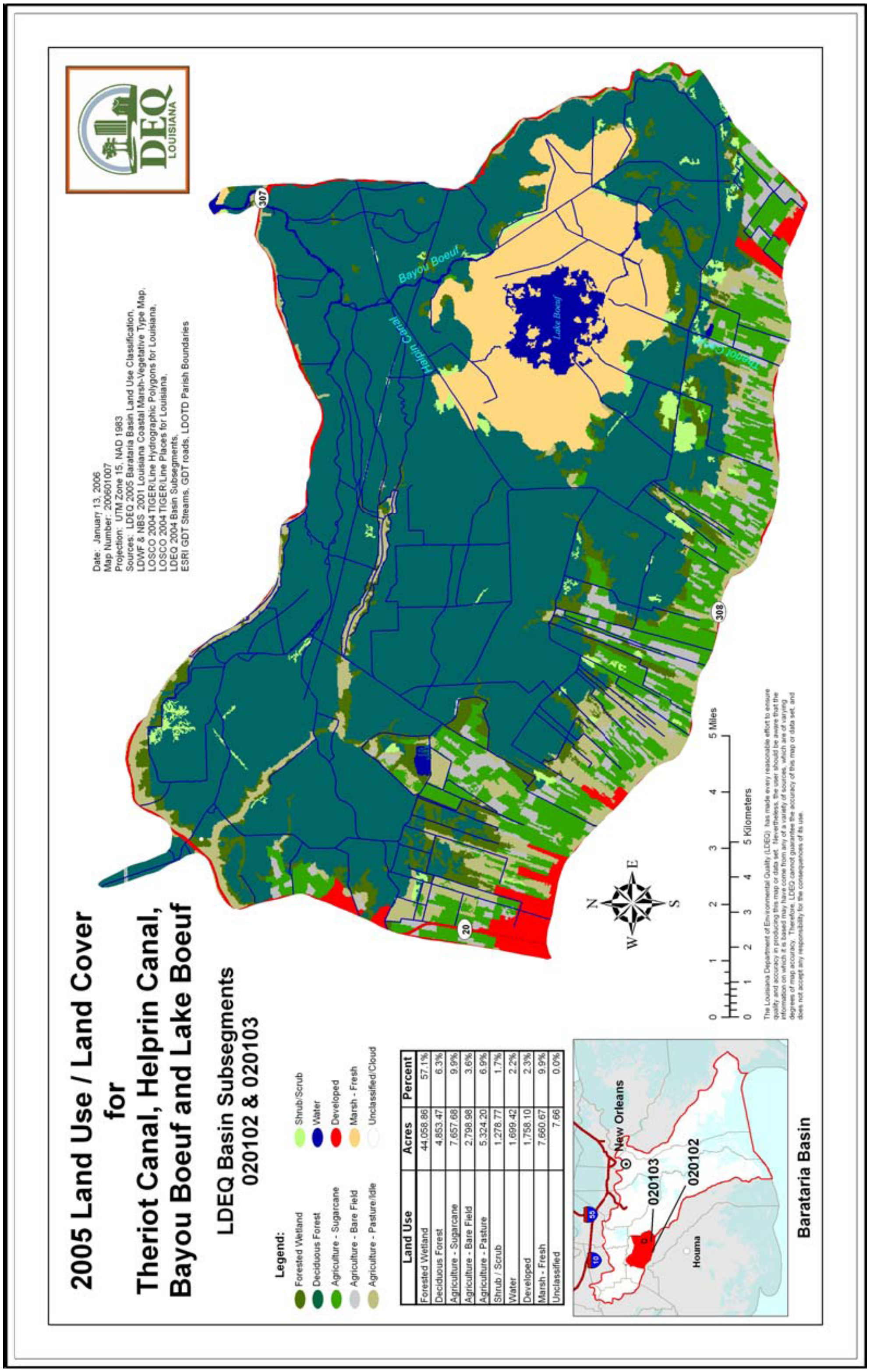

Figure 3: 2005 Land Use/Land Cover Map for Theriot Canal, Halpin Canal, Bayou Boeuf, and Lake Boeuf (Broad et al. 2006)

discrete locations represented in Table 5 and Figure 4.   The stations range from those directly affected by upland runoff to areas less affected by this runoff.

2.5 Water Quality

Discrete samples were taken in acid-washed polyethylene bottles, stored on ice, and taken to the laboratory for processing. Within 24-hours the water samples were sub-sampled into acid-washed bottles for TN and TP analysis. Also, 60 ml from each water sample were filtered through pre-rinsed 25 mm 0.45 um Whatman GF/F glass fiber filters into acid-washed bottles and frozen. The total and filtered water samples, and the filters, were frozen for nutrient and chlorophyll *a* analysis, respectively. Total suspended sediment (TSS) and salinity were measured using methods as described by Greenberg et al. (1985). Nitrate+nitrite (NO_x) was determined using the automated cadmium reduction method with an Alpkem © autoanalyzer (Greenberg et al. 1985). Ammonia+Ammonium (NH_x) was determined by the automated phenate method, phosphate (PO_4-P) by the automated ascorbic acid reduction method, and silicon (SiO_4-Si) by the automated molybdate reagent/oxalic acid method (Greenberg et al. 1985).   Total nitrogen (TN) and total phosphorus (TP) were determined by methods described by Valderrama (1981). All nutrients parameters were measured with an Alpkem© autoanalyzer, with the accuracy checked every 20 samples with a known standard, and the samples were redone if the accuracy was off by 5%. Chlorophyll *a* were determined by a modified version of the technique of Strickland and Parsons (1972).

The results of field collected data were then compared to existing data provided through Louisiana Department of Environmental Quality's (LDEQ) public information office. Both sets of data were used to establish the ambient water quality of the basin. In 2003 LDEQ completed the total maximum daily loads (TMDLs) for the Barataria Basin. The TMDL for Bayou Boeuf,

Table 5: Boeuf Basin – Sampling Sites

Sample Site	Location	Description
1	N29°53.437' W090°47.069'	Grand Bayou at LA-20
2	N29°51.508' W090°45.264'	St. James Bayou
3	N29°51.020' W090°40.729'	Grand Bayou
4	N29°50.967' W090°37.565'	Bayou Boeuf at Grand Bayou
5	N29°48.555' W090°40.687'	Halpin Canal at Rathborne Swamp
6	N29°50.194' W090°37.581'	Bayou Boeuf at Halpin Canal
7	N29°46.793 W090°37.322'	Theriot Canal at Lake Boeuf
8	N29°48.459' W090°37.388'	Bayou Boeuf at Lake Boeuf
9	N29°47.052' W090°35.601'	Bouie Canal (gas field intersection)
10	N29°48.863' W090°36.918'	Bayou Boeuf at Bouie Canal
11	N29°52.122' W090°35.730'	Bayou Boeuf at LA-307
12	N29°48.863' W090°38.862'	Theriot Canal at Bayou Lafourche

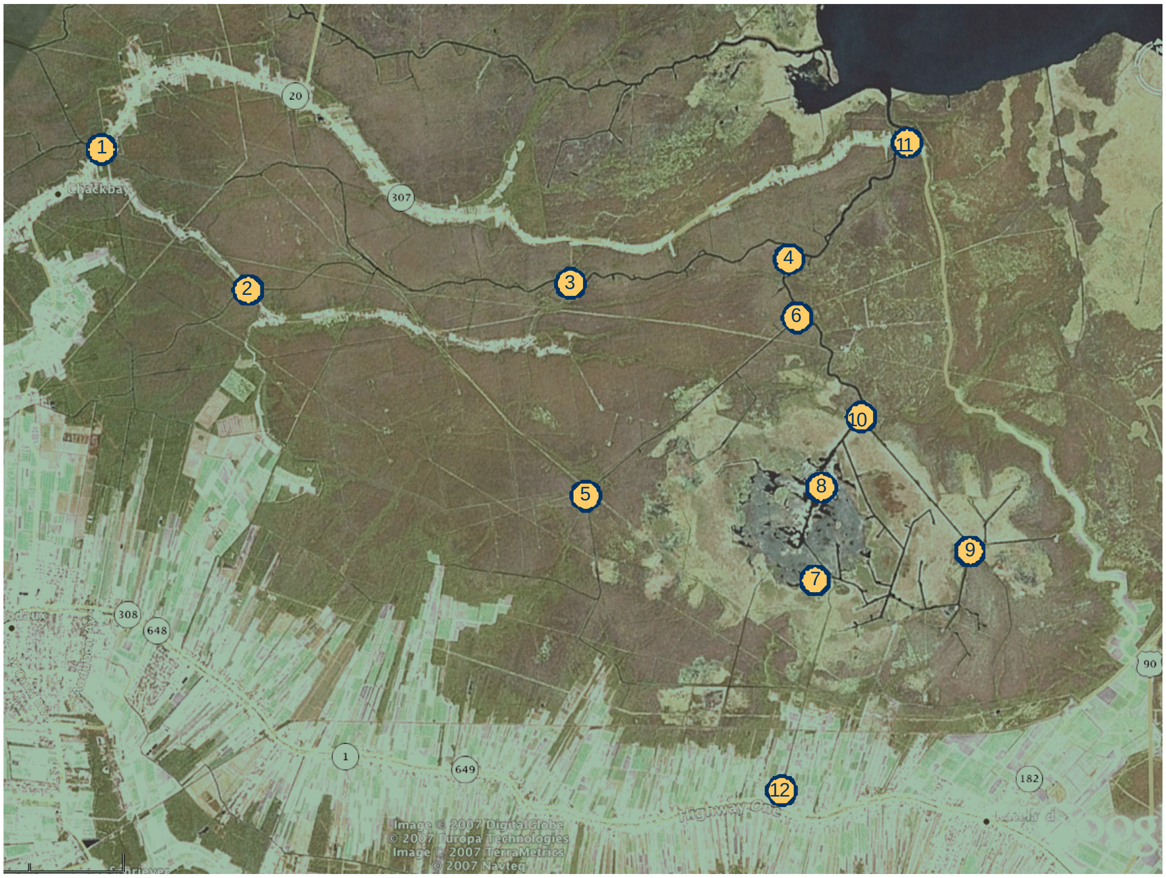

Figure 4: Field Sample Sites

Halpin Canal, Theriot Canal and Lake Boeuf specified that in order to meet the water quality standard for dissolved oxygen, NPS pollutants need to be reduced by 100% in the summer and 92% in the winter. The model also indicated that natural background loads would need to be reduced by 37% during the summer. The no-load scenario (i.e. no reductions in natural background loads) yielded minimum dissolved oxygen values of 3.5 mg/L for the summer and 5.6 mg/L for winter.

2.6 Nutrient Loading Analysis

The ability of wetlands to remove nutrients from inflowing water is primarily dependent on the nutrient concentration, volume of water discharged, and the area of wetlands available to receive the discharge. Nutrient uptake is also influenced by temperature and the hydrology of the specific wetland site. For example, when flow becomes channelized in a wetland, it decreases the physical interface and time of interaction between the effluent and the surrounding landscape, resulting in a less efficient nutrient removal system. Channelization has increased in the Boeuf Basin as agricultural managers have designed drainage canals that lead directly into the basin's web of canals and bayous and ultimately into the project area.

Nutrient input into a wetland is normally expressed as a loading rate that integrates nutrient concentration, volume of inflow, and area of the receiving wetland. This loading rate is generally expressed as the amount of nutrient introduced per unit area of wetland per unit time; normally as g of N or P per m^2/yr. Nutrient removal efficiency is the percentage of nutrients removed from the overlying water column and retained within the wetland ecosystem or released into the atmosphere. Richardson and Nichols (1985) reviewed a number of wetlands receiving municipal effluent and found a clear relationship between loading rate and nutrient removal efficiency (Figure 5). The relationship between nutrient removal efficiency and loading rate is not linear, with very efficient nutrient removal at low loading rates, and rapidly decreasing removal efficiency as loading rates rise. Mitsch et al. (2001) found a similar loading-uptake relationship for nitrate+nitrite (NO_x) in wetlands in the upper Mississippi River basin (Figure 6), and Mitsch et al. (2005) found that wetlands in the upper and lower Mississippi River remove NO_x at similar rates.

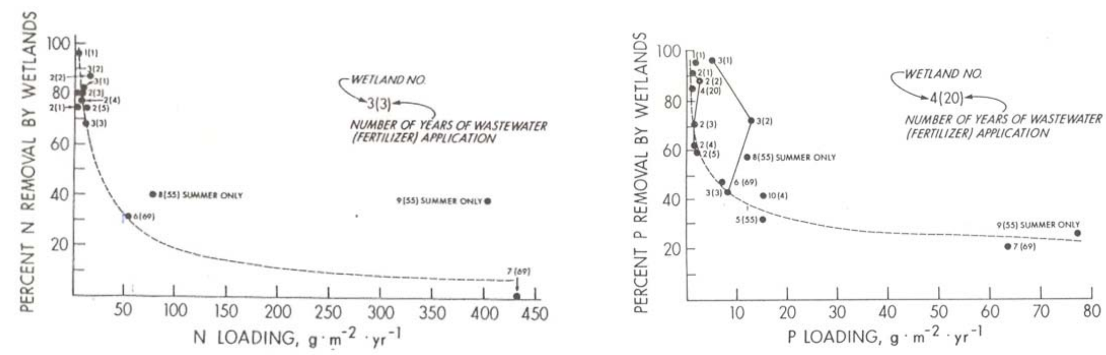

Figure 5: Nitrogen and phosphorus removal efficiency as a function of loading rate in various municipal effluent assimilation wetlands (Richardson and Nichols 1985).

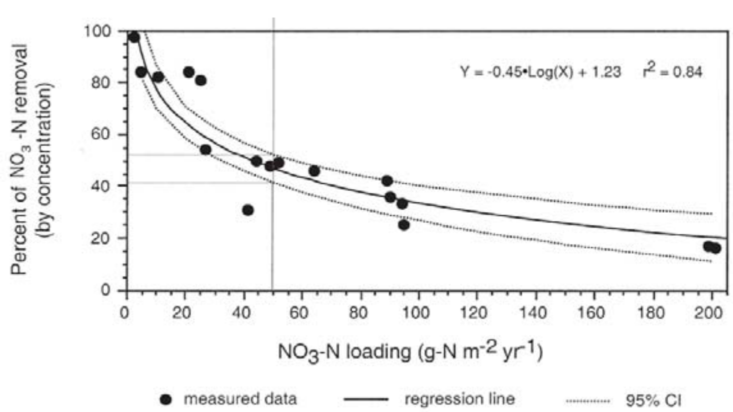

Figure 6: Nitrate removal by concentration versus nitrate loading for constructed wetlands in the midwestern United States (Mitsch et al 2001).

The curves of Richardson and Nichols (1985) are derived from data of wetland assimilation systems located in many different parts of the United States. Day et al. (2004) showed that this relationship was generally true for wetlands in Louisiana. Nutrient uptake has also been reported in coastal wetlands receiving Atchafalaya River water (Lane et al. 2002), and Mississippi River water (Lane et al. 1999, 2004).

CHAPTER 3: RESULTS

3.1 Field Sampling Results

NOx levels throughout the study ranged from 0.00 to 0.65 mg/L with a mean of 0.06 mg/L and a S.E. of ± 0.01 mg/L (Figure 7). Spikes in concentration occurred primarily at site 12 from December through February suggesting that NOx enters the basin via Theriot Canal. Site 12, located at the south end of Theriot Canal, is bordered on the east and west by sugarcane fields and drainage ditches. During the months of high concentration, the majority of fields were bare and had no cover crops allowing excess nitrogen to run off into the neighboring canal. In addition, the water budget analysis showed that the winter is the time when precipitation greatly exceeds evapotransporation and there is a high net surplus of water. It is not surprising that NOx levels are low since nitrate can be readily denitrified in the wetlands and sediments of the Boeuf Basin.

PO_4 concentrations ranged from 0.01 to 1.26 mg/L with a mean of 0.10 mg/L and a S.E. of ± 0.02 mg/L (Figure 8). There was one spike of 1.264 mg/L which was much higher than the next highest value of 0.34 mg/L. Levels tended to be higher at sites 1, 2, and 3, suggesting that the majority of PO_4 enters from the west via St. James Canal and Grand Bayou. St. James Canal drains a portion of Thibodaux suggesting the higher PO_4 levels may be related to urban runoff as well as agricultural runoff.

The high concentration spike at site 9 in December may have been due to agricultural runoff channelized through the southern end of Bowie Canal. Agricultural acreage in this area is impounded on the south and eastern boundaries, forcing drainage to the north towards site 9. However, the lack of additional spikes during the study period suggests that the high concentration is atypical of mean levels.

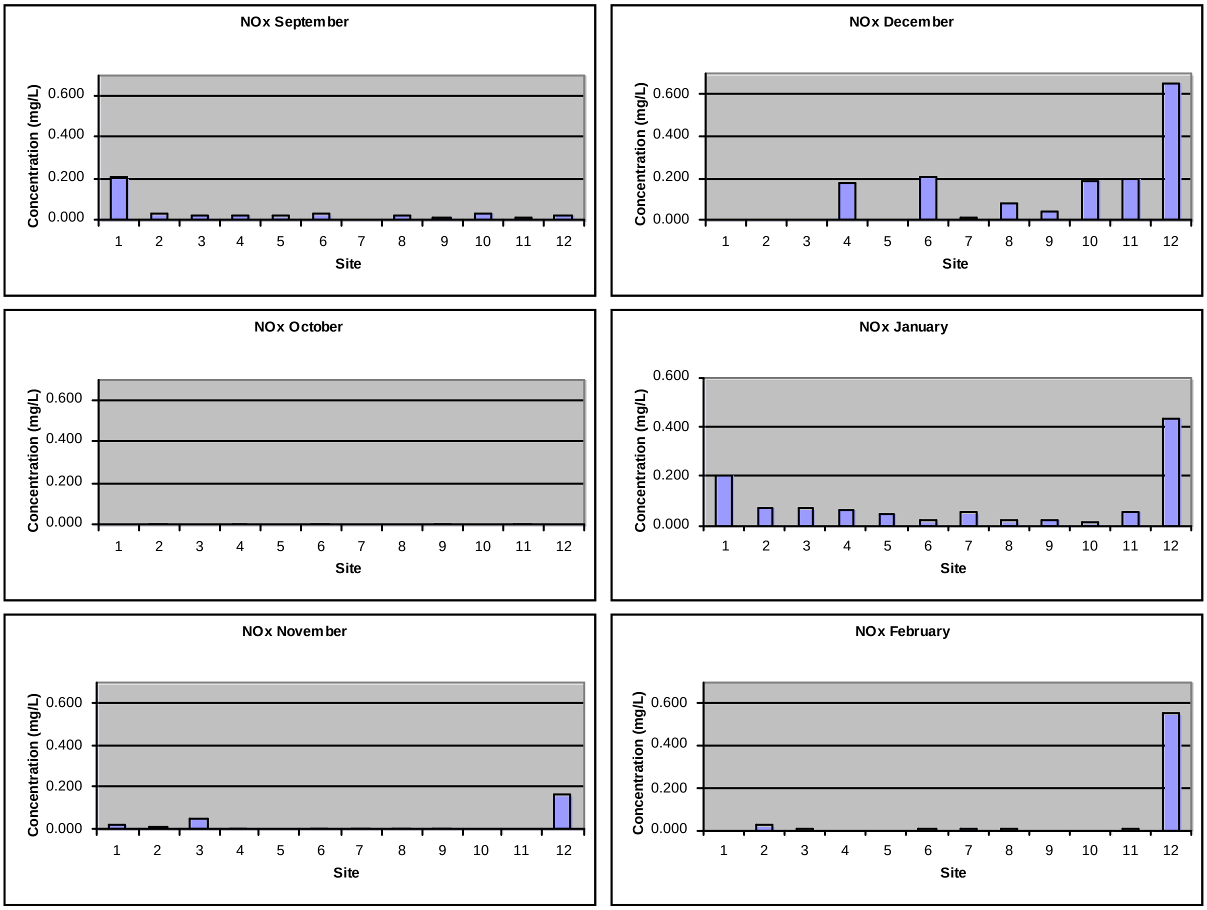

Figure 7: NOx concentrations in the Boeuf basin collected from September 2007 through February 2008.

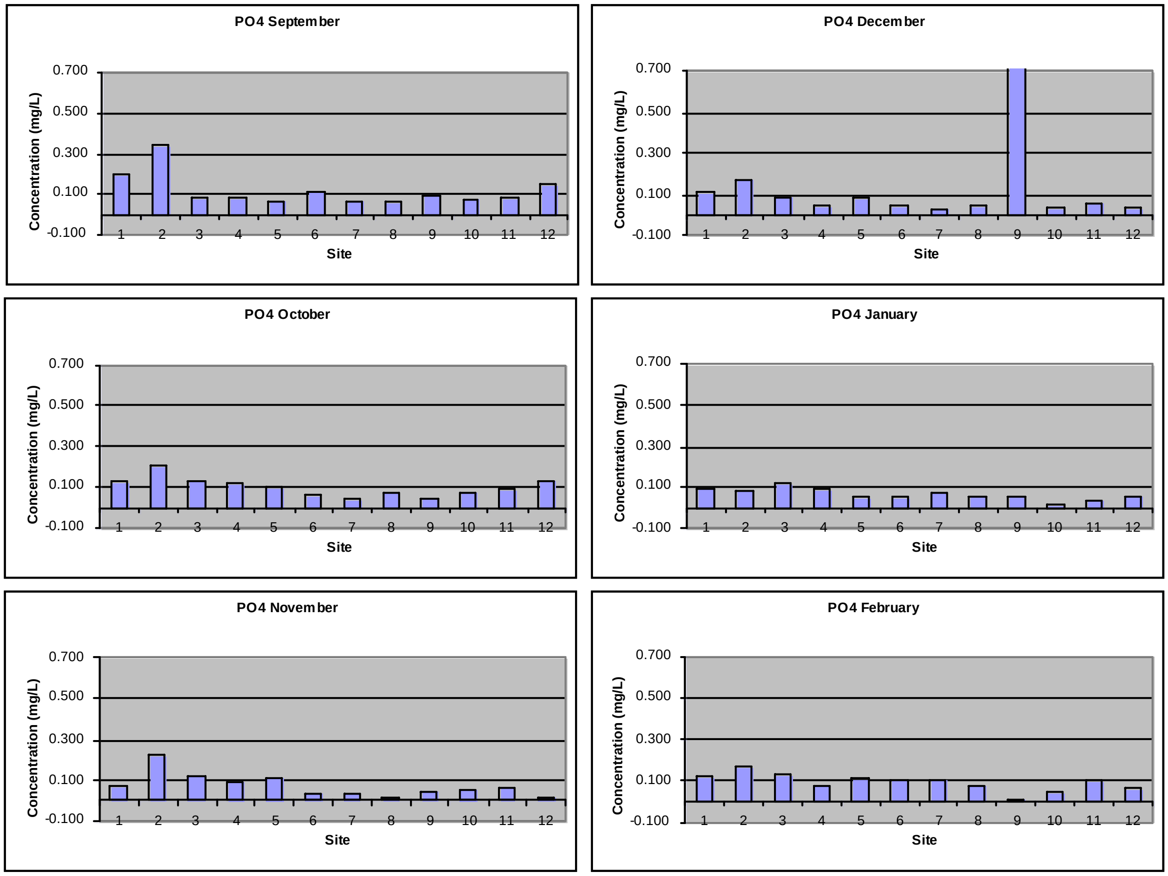

Figure 8: PO$_4$ concentrations in the Boeuf basin collected from September 2007 through February 2008.

Silicate concentrations ranged from 0.02 to 2.43 mg/L with a mean of 0.97 mg/L and a S.E. of ± 0.05 mg/L (Figure 9). Overall levels rose from September through December and dropped in January and February. Concentrations tended to be higher at stations 1, 2, 3, 5, 9, and 12 suggesting an upland source for silicate.

NH4 levels ranged from 0.06 to 0.36 mg/L with a mean of 0.13 mg/L and a S.E. of ± 0.01 mg/L (Figure 10). Levels remained fairly constant with a greater number of spikes occurring in December. Stations directly affected by upland runoff did not tend to have high levels of ammonia. This suggests that internal recycling in the wetland-aquatic system, as well as upland runoff, affected ammonia levels.

As expected, salinities in the project area were low and ranged from 0.1 to 0.3 ppt with a mean of 0.1 ppt and a S.E. of ± 0.01 ppt (Figure 11) essentially confirming that the system is fresh.

TSS concentrations ranged from -9 mg/L to 496 mg/L with an average of 26 mg/L and a S.E. of ± 7.38 mg/L (Figure 12). Concentrations were generally low with most values below 50 mg/l. Higher concentrations occurred in January and the largest spikes were at site 12, which is directly affected by agricultural runoff. Water observed at site 1 was very muddy and was reflected as such in the data. Minor spikes at sites 7 and 8 in September may be representative of drilling observed at site 7 on the collection date. Average rainfall in January in Lafourche Parish, Louisiana is 6.13 inches. Again, site 12 is located within the agricultural acreage, making higher concentrations predictable.

3.2 Basin-wide Concentrations

In addition to analyzing the data by site, it was important to establish basin-wide concentration means for the study area. By combining nutrient concentration data from each of

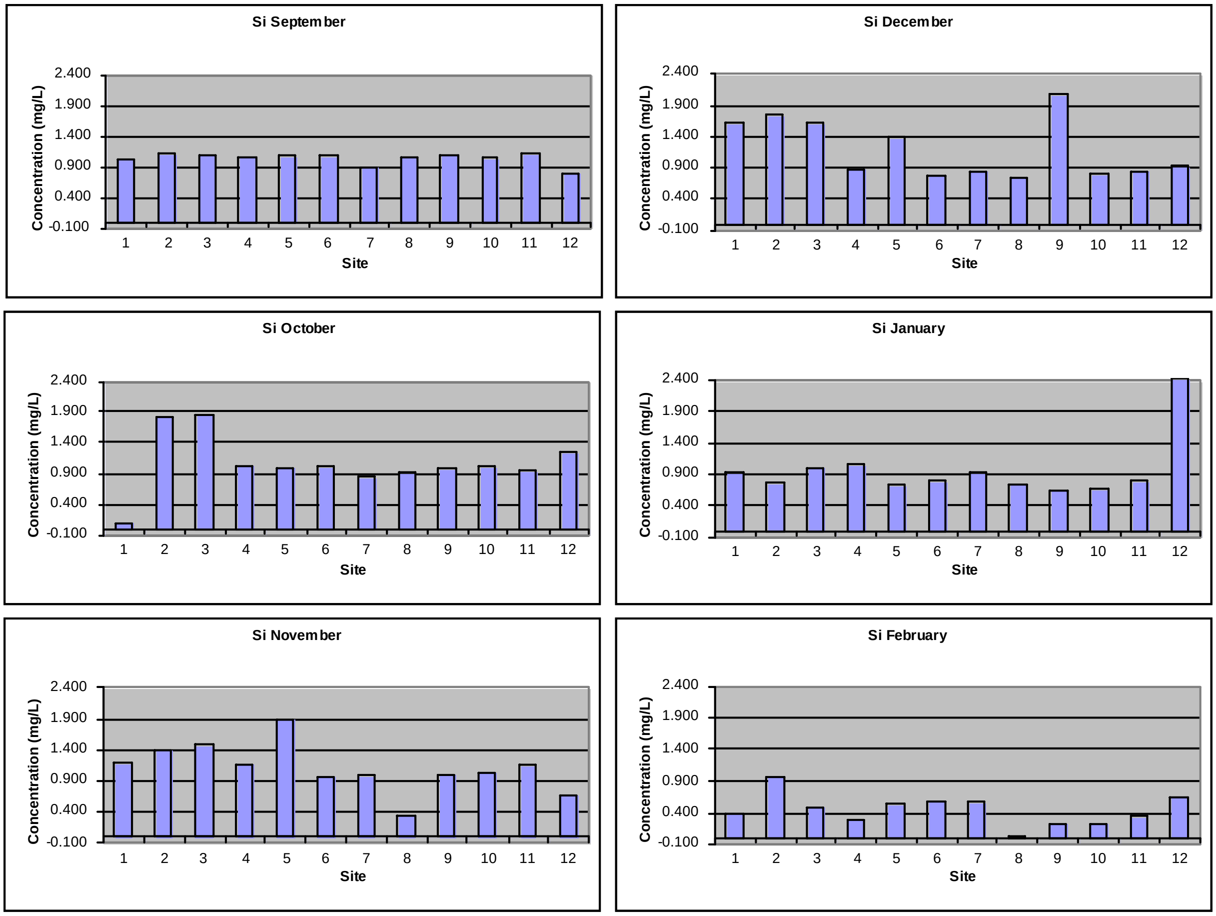

Figure 9: Si concentrations in the Boeuf basin collected from September 2007 through February 2008.

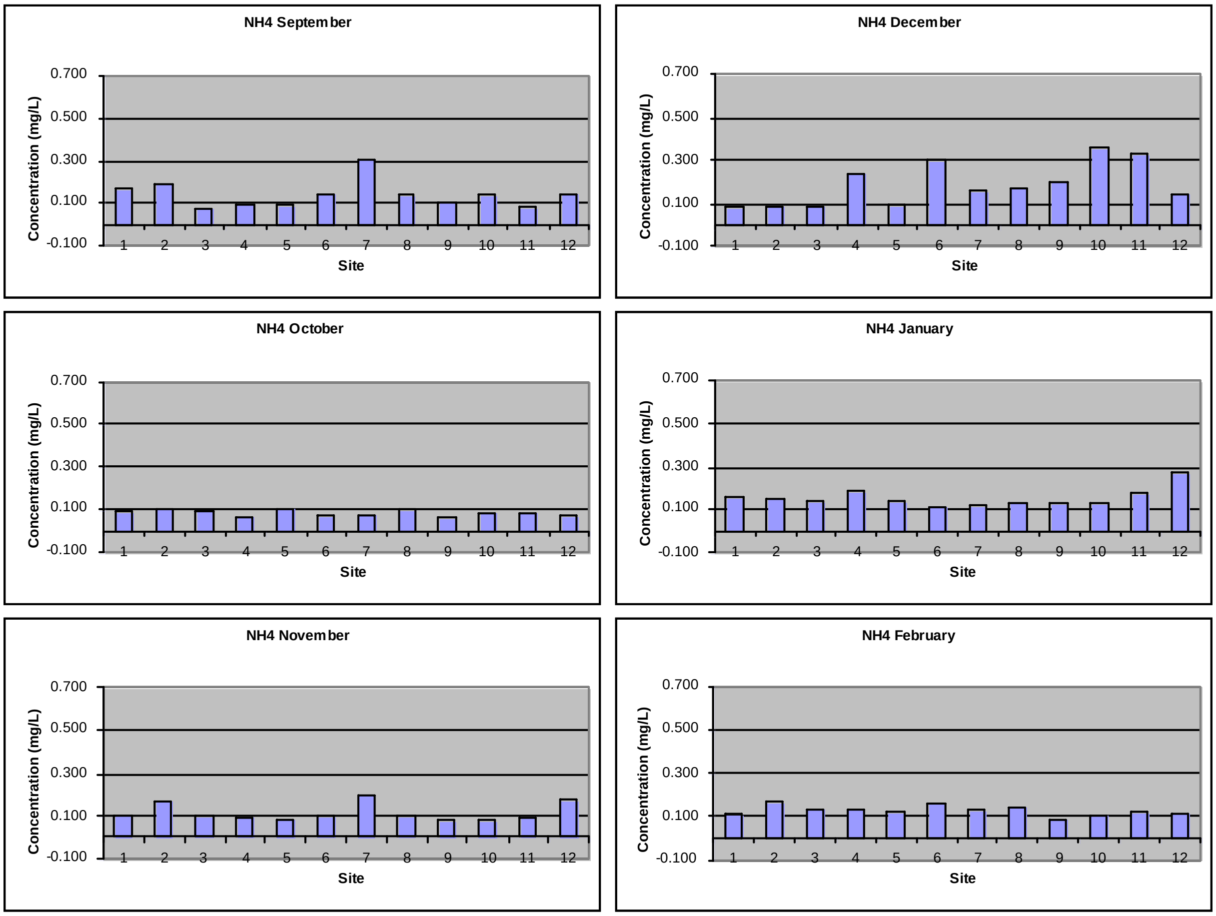

Figure 10: NH_4 concentrations in the Boeuf basin collected from September 2007 through February 2008.

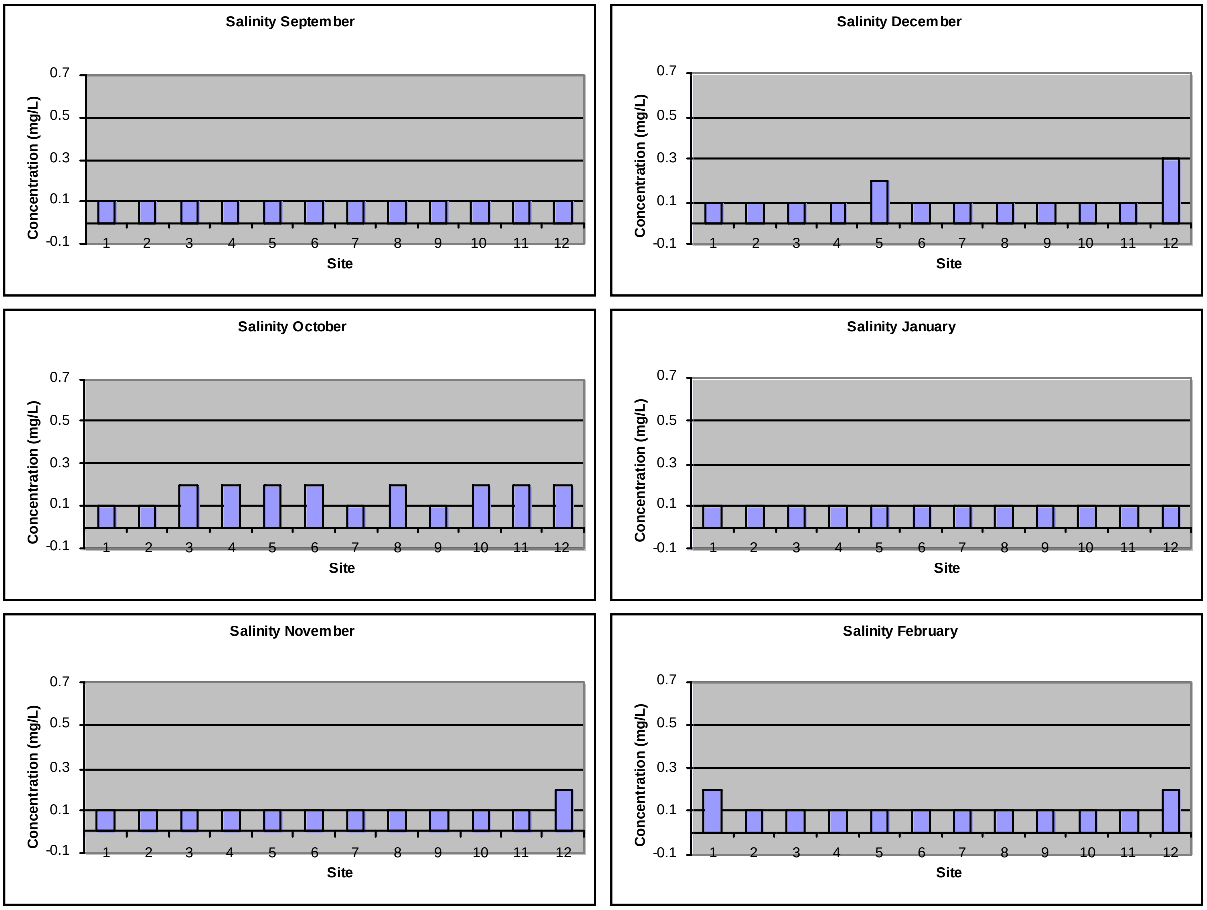

Figure 11: Salinity concentrations in the Boeuf basin collected from September 2007 through February 2008.

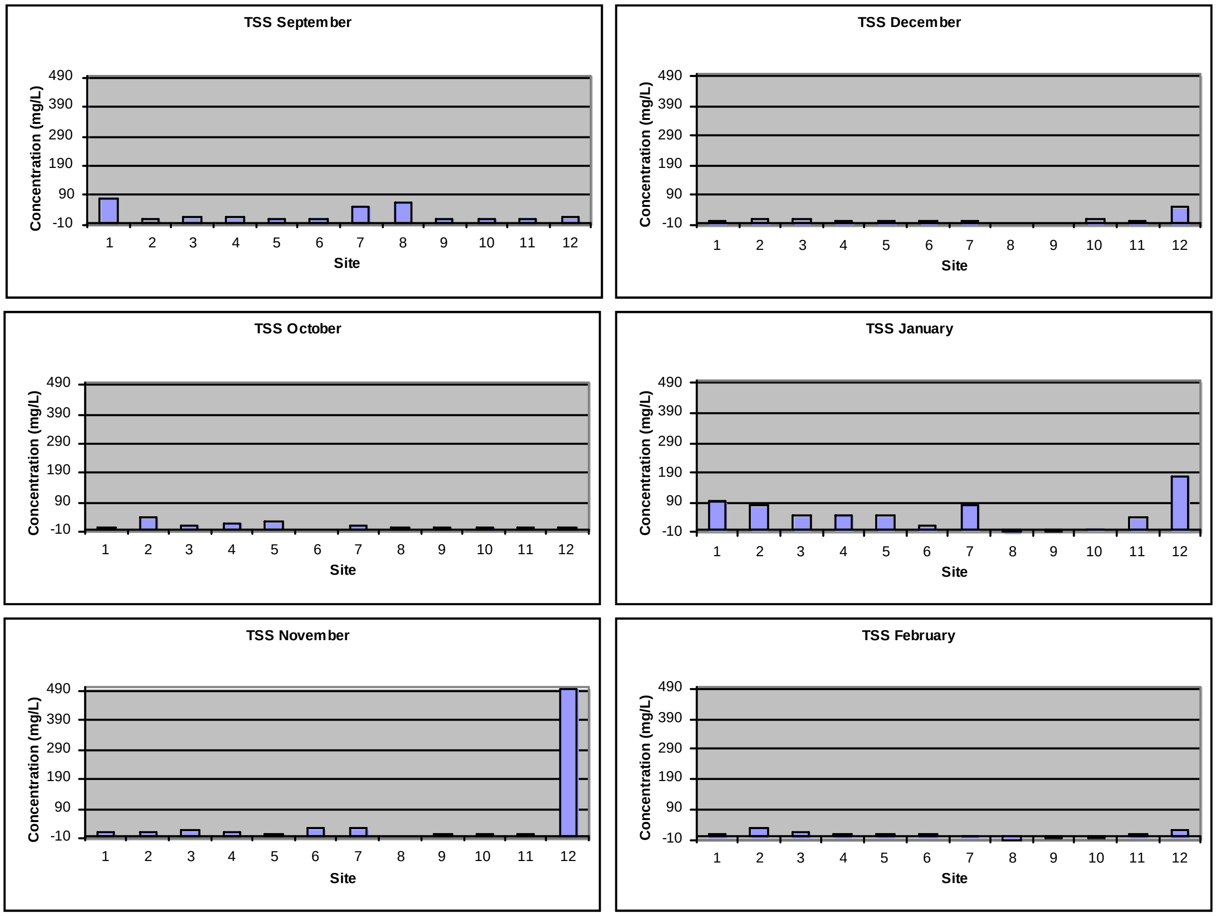

Figure 12: TSS concentrations in the Boeuf basin collected from September 2007 through February 2008

the twelve sites, I was able to get a basin-wide average represented in Table 6. As illustrated basin-wide nutrient concentrations were relatively low. This implies that the system is not tremendously degraded making better water quality for this basin achievable.

Table 6: Mean Concentrations of Field Samples in Boeuf Basin

Sample collection dates	**Mean concentrations of field samples in Boeuf Basin**					
	NO3 mg/L	PO4 mg/L	Si mg/L	NH4 mg/L	Salinity ppm	TSS mg/L
14-Sep-07	0.04	0.00	1.04	0.14	0.1	25
12-Oct-07	0.00	0.10	1.06	0.09	0.1	10
16-Nov-07	0.02	0.08	1.12	0.12	0.1	51
14-Dec-07	0.13	0.17	1.19	0.19	0.1	9
18-Jan-08	0.09	0.07	0.96	0.15	0.1	52
29-Feb-08	0.05	0.09	0.44	0.13	0.1	8
Basin-wide Average	0.06	0.11	0.97	0.14	0.10	25.83
S.E. of the mean	0.02	0.02	0.11	0.01	0.00	8.51

In order to determine whether or not precipitation had affected nutrient concentration data, I felt it necessary to compare concentrations and the relation to rain events occurring seven days prior to collection. Unfortunately, daily precipitation for the study area during the collection period (September 01, 2007 - February 29, 2009) was all measured at 0.00 (in). There were registered rain events occurring during that time period. Events recorded seven days prior to collection are presented in Table 7. These events were then compared to the mean basin-wide concentrations. Casual observation suggests no causal relationship between basin-wide nutrient concentrations and precipitation. However, the lack of measureable precipitation recorded during the study period provided little data for analysis and registered rain events were likely isolated events that provided little measurable precipitation.

(http://www.wunderground.com/history).

Table 7: Rain events occurring one week prior to sample collection dates and mean concentrations of nutrients in Boeuf basin. (http://www.wunderground.com/history)

Rain events occurring one week prior to sample collection dates								**Mean concentrations of nutrients in Boeuf Basin**					
Sample collection dates	*Days Prior*							*Nutrient concentrations*					
	1	2	3	4	5	6	7	NO3 mg/L	PO4 mg/L	Si mg/L	NH4 mg/L	Salinity ppm	TSS mg/L
14-Sep	X		X					0.04	0.00	1.04	0.14	0.1	25
12-Oct				X	X	X	X	0.00	0.10	1.06	0.09	0.1	10
16-Nov					X			0.02	0.08	1.12	0.12	0.1	51
14-Dec		X			X			0.13	0.17	1.19	0.19	0.1	9
18-Jan		X						0.09	0.07	0.96	0.15	0.1	52
29-Feb								0.05	0.09	0.44	0.13	0.1	8

3.3 Louisiana Department of Environmental Quality Data

Water quality measurements were compiled by the Louisiana Department of Environmental Quality (LDEQ) for the Boeuf basin in years 2000, 2004, and 2005. Samples collected in 2000 were obtained monthly and samples taken in 2004 and 2005 were irregular. High, low, and mean concentrations are represented in Table 8.

Table 8: Nutrient concentrations in Boeuf basin collected by LDEQ (2000, 2004, and 2005)

Nutrient concentrations in Boeuf basin collected by LDEQ from							
		NO3	PO4	NH4	Salinity	TSS	TN
Site 6	High	1.43	0.91	0.24	3.8	24	2.38
	Low	0.02	0.06	0.1	0	5	0.83
	Mean	0.08	0.14	0.18	0.83	6.49	1.62
Site 7	High	0.26	0.32	0.56	3.6	26.7	1.94
	Low	0.02	0.1	0.1	0	0	0.57
	Mean	0.07	0.16	0.17	0.80	7.47	1.17

Comparison of field collected data to that of LDEQ resulted in mean discrepancies as outlined in Table 9.

Table 9: Nutrient concentrations among identical sample sites of field collected and LDEQ data.

Nutrient concentrations among identical sample sites of field collected and LDEQ data.							
		NO3	PO4	NH4	Salinity	TSS	TN
Site 6	High	1.43	0.91	0.24	3.8	24	2.38
	Low	0.02	0.06	0.1	0	5	0.83
	LDEQ mean	0.08	0.14	0.18	0.83	6.49	1.62
	Field collected mean	0.05	0.07	0.15	0.12	9.67	0.00
	Mean Difference	*0.03*	*0.07*	*0.03*	*0.71*	*-3.18*	*1.62*
Site 7	High	0.26	0.32	0.56	3.6	26.7	1.94
	Low	0.02	0.1	0.1	0	0	0.57
	LDEQ mean	0.07	0.16	0.17	0.80	7.47	1.17
	Field collected mean	0.01	0.06	0.16	0.10	29.33	0.00
	Mean Difference	*0.06*	*0.10*	*0.01*	*0.70*	*-21.87*	*1.17*

3.4 Ambient Water Quality

Field data were compared to water quality measurements taken by LDEQ. This data was collected in 2000, 2004, and 2005 when developing total maximum daily loads for the basin. Sites 6 and 7 were the common sampling sites among the two data sets and by merging this data I was able to establish an ambient background of water quality for those two sites. JMP statistical software (Sall et al. 2005) was used to produce a linear slope and test for significant differences between the slope of the regression and the mean (alpha <0.05) (See appendices). High, low, and mean concentrations are presented in Table 10.

Table 10: Comparison of field collected and LDEQ nutrient data for two identical sampling locations.

Composite high, low, and mean concentrations from collected field and LDEQ data							
Site		**NOx mg/L**	**PO4 mg/L**	**Si mg/L**	**NH4 mg/L**	**Salinity ppt**	**TSS mg/L**
6	High	0.21	0.11	1.09	0.30	0.2	24
	Low	0.01	0.04	0.60	0.05	0.1	-2
	Avg.	0.05	0.07	0.87	0.15	0.1	10
7	High	0.05	0.10	1.00	0.30	0.1	83
	Low	0.00	0.03	0.57	0.08	0.1	4
	Avg.	0.01	0.06	0.85	0.16	0.1	29

An analysis of variance for sites 6 and 7 illustrated a significant decrease in PO4 and salinity over the time of data collection (Appendix A). The decline in PO_4 concentrations may indicate an increase in bmp adoption by agricultural managers, while salinity decrease can be attributed to drought conditions in 2000. During this time, salinities were high as the area had very little fresh water to combat salt water intrusion.

3.5 Loading Rate Analysis

DeLaune et al. (2007) investigated the impact of nonpoint source pollution associated with sugarcane production in St. James Parish, LA. Water flux and water quality data was collected from two different sugarcane fields with differing soil porosities. This data was used to provide a high and low estimate of loading rates from the sugarcane fields. These rates are as follows:

- NOx: 0.26-4.56 g/m2/yr
- NH4: 0.15-1.55 g/m2/yr
- TKN: 1.31-5.33 g/m2/yr
- TN: 1.57-9.90 g/m2/yr
- TP: 0.47-1.32 g/m2/yr
- TSS: 79-625 g/m2/yr

Applying these rates to the area of sugarcane fields in the Boeuf basin (30,989,127 m2) provides an estimate of nutrient loads for the study area (Table 11).

Table 11: Nutrient loading estimates from sugarcane fields into Boeuf basin

Nutrient loading estimates from sugarcane fields into Boeuf basin						
	NOx *(g /yr)*	NH4 *(g/yr)*	TKN *(g/yr)*	TN *(g/yr)*	TP *(g/yr)*	TSS *(g/yr)*
Low	8,057,173	4,648,369	40,595,756	48,652,929	14,564,890	2,448,141,033
High	141,310,419	48,033,146	165,172,047	306,792,357	40,905,648	19,368,204,375

The Boeuf basin contains 51,719.53 acres of forested wetland and fresh marsh. This area compared to total yield allows the calculation of nutrient yields from the sugarcane fields on an m^2 basis (Table 12).

Table 12: Loading rate estimates for Boeuf basin

Yield/Area ratio for Boeuf Basin						
	NOx *(g /m2/yr)*	NH4 *(g/m2/yr)*	TKN*(g/m2/yr)*	TN *(g/m2/yr)*	TP *(g/m2/yr)*	TSS *(g/m2/yr)*
Low	.038	.022	.194	.232	.070	11.697
High	.675	.038	.789	1.466	.195	92.537

When using only high yield estimates yield to area ratios are applied (in red) to figures 5 and 6 (reprinted below as Figures 13 and 14), one can see that only ~10% of the available wetland forest and fresh marsh are needed to remove 100% of nitrate, total nitrogen, and total phosphorous.

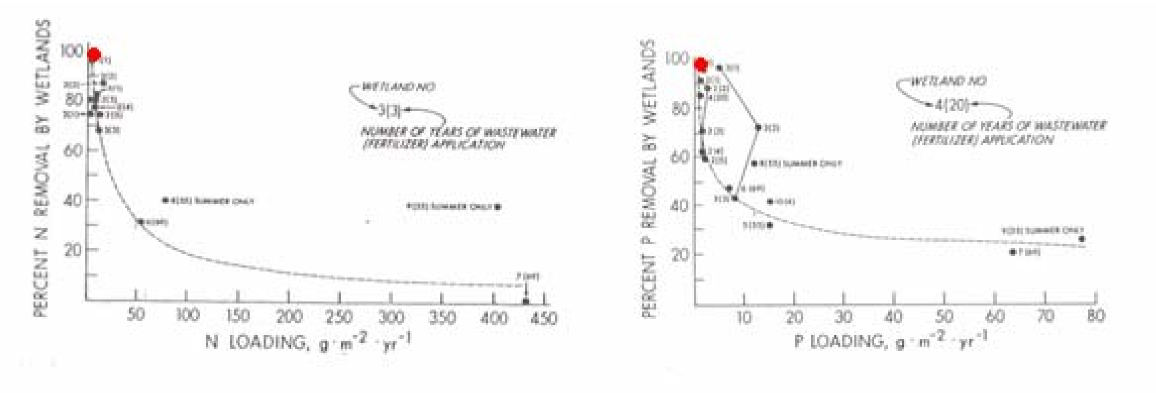

Figure 13: Nitrogen and phosphorus removal efficiency as a function of loading rate in various municipal effluent assimilation wetlands (Richardson and Nichols 1985)(Edited in red).

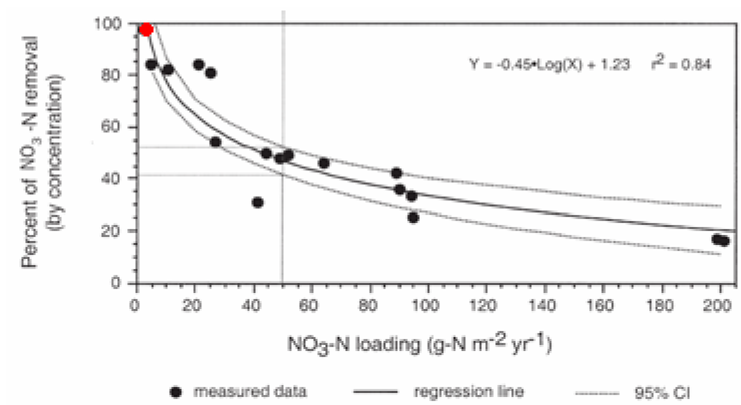

Figure 14: Nitrate removal by concentration versus nitrate loading for constructed wetlands in the midwestern United States (Mitsch et al 2001) (Edited in red).

CHAPTER 4: DISCUSSION AND RECOMMENDATIONS

4.1 Summary

The Boeuf basin is an ecologically unique environment with its floating marshes and forested wetlands that function as a freshwater reservoir in the upper reaches of Barataria basin; a basin with some of the highest rates of land loss in Louisiana’s coastal zone (Barras, 1994) . Therefore, it is imperative that the Boeuf system have good water quality. Wetlands can help maintain water quality by retaining and processing nutrients from adjacent urban and agricultural areas. Though data shows that nutrient concentrations and loading rates into the system are not excessively high, there still needs to be some form of improved management. One of the main problems is that most water flowing off the uplands is channelized and does not flow over wetlands. The occurrence of channelization is similar to previous findings established by Mitsch et al. (2001) and Boody et al. (2005).

The majority of high nutrient concentration spikes occurred at site 12. Because this site is located directly adjacent to agricultural fields, higher sample readings are not unexpected. This site receives regular runoff from the surrounding agricultural fields and drainage ditches from these fields flow directly into the canal. Management of agricultural acreage around this site is critical for reduction of nutrients that have the ability to leach from the fields (Chambers et al. 2006).

4.2 Agriculture

Advances in agriculture have transformed crop production in the Lake Boeuf region. Original settlers in the area utilized the banks of Bayou Lafourche for agricultural land. The soils along these natural levees were well suited for agriculture due to rich alluvium deposited by spring floods. As hydrologic modification occurred in the area, the farm lands were deprived of the annual nutrient-rich deposits. Agricultural turnover, in addition to diminished flooding has ultimately reduced the amount of nutrients remaining in the soil. Therefore, in order to maintain consistent crop production, land managers have increased fertilizer use.

Effective drainage management has also been a regular concern among area farmers. To facilitate proper drainage of their fields, drainage ditches were dug into the landscape. These ditches were designed to drain into nearby water bodies and as they became more efficient, runoff of excess fertilizers from the fields increased. Channels dug in the wetlands allowed runoff to flow directly to water bodies rather than filtering through wetlands.   These loadings are higher in concentration during the cooler months when there is surplus water and the fields are bare and contain no cover crops to impede runoff. Manipulation of crop strains has increased production and improved pest, drought, and disease resistance. However, there is a need for further investigation of strains that require less fertilization.

4.3 Best Management Practices

One of the most effective ways to reduce nutrient loading of fertilizers from sugarcane fields into the Bouef basin is to implement a series of best management practices (NRCS Planning and Design Manual, 1994). Loadings into the basin primarily occur along Theriot Canal, where drainage ditches from the fields run directly into the canal. Use of vegetative plantings along the edges of these drainage ditches would diminish the amount of nutrients that reach the ditches. It was observed during site visits that the majority of sugarcane residue in the fields was burned after harvest. Allowing this residue to remain or planting cover crops after harvest would be extremely beneficial in reducing the amount of surplus fertilizer that runs off into the Boeuf basin. Recommended bmps for nutrient concentration reduction into Boeuf basin from agricultural drainage include, drainage canal vegetation; sheet flow dispersion;

erosion control blankets; use of cover crops/non burn; and gabions, where necessary. Unfortunately, findings on the adoption of best management practices by Louisiana farmers are not extraordinarily promising (Zhong 2003). Perhaps the most effective way to reduce nutrients from reaching waterbodies like Lac des Allemands is to have runoff flow through wetlands

4.4 Policy recommendations

Educational programs for implementation of best management practices have proven successful (Feather and Cooper, 1995) when they can effectively emphasize benefits and proposing cost-effective options. Therefore, capable educators should be employed to work with the area farmers to increase bmp adoption.

Direct introduction of agricultural runoff to waterways via agricultural drainage ditches should be minimized and flow through wetlands should be maximized. If bmp adoption is low after sufficient educational efforts, landowners should be strongly encouraged to implement these practices. Programs such as the Conservation Reserve Program (CRP) and Conservation Reserve Enhancement Program (CREP) provide ample opportunity for low-cost implementation of beneficial management of croplands.

Fertilizer application and water management in the project area should be monitored and efforts to introduced bmps should be focused on areas where there is high runoff into waterways. Programs such as the Agricultural Extension network should work with farmers in these areas to implement effective bmps.

4.5 Wetland Assimilation

By diverting agricultural runoff through wetlands, nutrient loads to Lac des Allemands can be greatly diminished. Evidence of nitrogen and phosphorous removal by wetlands has been established (Day et al. 2003) and there is an ample area of wetland available for assimilation of nutrient loads within the project area. Only a small portion (~10%) is needed to completely remove nutrients flowing into the system and this can be accomplished by segmenting the agricultural area and diverting drainage from each area directly into the wetland. However, in order to establish the size and location of individual receiving wetlands, it is necessary to determine the area of sugarcane fields in each segment and the wetlands needed for each. These wetlands should be proximal to the sugarcane fields allowing for assimilation to begin where runoff enters the wetland area.

Existing drainage ditches adjacent to the sugarcane fields need to be plugged and vegetated to prevent direct drainage into the canal. Drainage should be redirected and forced to exit the fields directly into the wetlands. By loading these excess nutrients into the wetlands instead of the waterways, the nutrients would be assimilated and spur productivity within the receiving wetland (Day et al. 2004, Lane et al. 2006) rather than being channelized. For areas where channelization cannot be avoided, a series of weirs should be installed to allow for diversion of this channel water into the surrounding wetlands.

4.6 Implications of Energy Scarcity

With the rapidly rising price of fossil fuels, ecological restoration costs will continue to climb (Day et al. 2005). Therefore, the need for restoration plans that employ ecological engineering techniques will be required to achieve cost-effective outcomes. Restoration efforts often take years to complete planning and design phases leading to eventual project costs well in excess of original projection estimates. By employing ecological engineering principles in these designs, initial cost estimates and cost increases can be dramatically reduced. Once constructed, the operation and maintenance of these ecologically engineered projects would also require lower costs than those of traditional designs that are heavily dependent on fossil fuels.

Oil and gas are the primary sources of fossil fuels, and as prices continue to rise more rapidly than inflation, construction costs will also continue to rise. Currently, Louisiana's coastal restoration effort is under funded while proven viable planned and engineered projects remain designed and ready for construction. These projects languish until authorization, at which time newly calculated construction costs vastly exceed the original cost projections. As fuel prices continue to increase, wetland restoration projects will become more and more difficult to build and maintain unless they are made more energy efficient.

4.7 Long Term

Through careful management and implementation of best management practices and ecologically engineered design, the Boeuf basin can become be a healthy, productive ecosystem that meets established total maximum daily load standards. The freshwater habitat provides a diverse ecological habitat within the Louisiana coastal zone. By using both best management practices and ecological engineering principals, restoration of the Boeuf basin should be of modest cost and thereby less difficult to construct and maintain. As the area of farm acreage becomes more leached of alluvial nutrients, the need for fertilization will increase. Proper management of both fertilizer and irrigation will aid in alleviating runoff into the project area. One recommendation for improving the soil health of these acreages is to allow certain fields to remain fallow throughout the year and place impoundments around the acreage to allow for flooding by river water. Flooding of these tracts would allow for deposition of more sediment and nutrients, which would improve crop production into the subsequent growing seasons.

4.8 Future Research

Loading estimates were established using previous data sets taken from areas near, but not within, the project area. In order to get better loading rate estimates for the project area, flow rates need to be measured at the point of runoff entry into Theriot Canal. The majority of loadings occur during rain events and higher concentrations occur during the cooler months post field harvest. Data collection during these months and immediately following rain events would provide a better estimate of nutrient loadings into the Boeuf basin.

In addition to measuring more precise loads into the basin, agricultural and receiving wetland areas need to be more precisely measured and segmented. Phosphorous and nitrogen concentrations in sugarcane field soils should also be measured. Values of nitrogen and phosphorous levels in the soils can suggest how over/under fertilized the average sugarcane acreage is. By establishing efficient fertilizer applications rates, harvest managers can better regulate appropriate fertilization rates for the adjoining agricultural acreage.

Within the Boeuf basin resides an 802 acre Lake Boeuf Wildlife Management Area (WMA). The WMA is utilized throughout the year for varying recreational activities. Therefore, cooperation between the WMA and basin managers is recommended when developing management strategies. Issues of landrights and the need for flowage easements will need to be addressed prior to implementation of flow structures and drainage diversions.

CHAPTER 5: CONCLUSION

Overall nutrient concentrations recorded in the Boeuf basin were lower than expected, but management of agricultural runoff is still a necessity. Improved management of acreage surrounding site 12 should be the first priority as evidenced by it's higher than average readings in the basin. By applying watershed management goals recommended by Elshorbagy et al. (2005) to the management strategy for the Boeuf Basin, the watershed will be rehabilitated, protected from future over nutrification, and enhanced. Implementation of best management practices and drainage diversions into nearby wetlands should provide for effective reductions in nutrient concentrations for the basin, thus achieving the above management goals.

Other freshwater basins within Louisiana's coastal zone experience many of the same issues as Boeuf Basin. Subsidence, stormwater runoff, and low dissolved oxygen are persistent concerns for these basins and the same management strategies recommended for Boeuf Basin can be applied to these watersheds. Therefore, in order to effectively improve the water quality of Boeuf Basin and similar watersheds, implementation of the model outlined in Figure 15 is recommended. This model includes the use of best management practices (BMP), ecological engineering, and existing programs and regulations to improve water quality. These practices should be implemented throughout the aforementioned three phases or management periods; agricultural management, nutrient loading, and post-channelization.

Best management practices can be implemented during the agricultural management and nutrient loading phases. During the agricultural management phase, landowners have a variety of methods available to reduce nutrient runoff from fields. These practices have been outlined by USDA and should be made increasingly cost-effective. Educational programs should be revamped to provide maximum benefit to Louisiana landowners. By making BMPs more

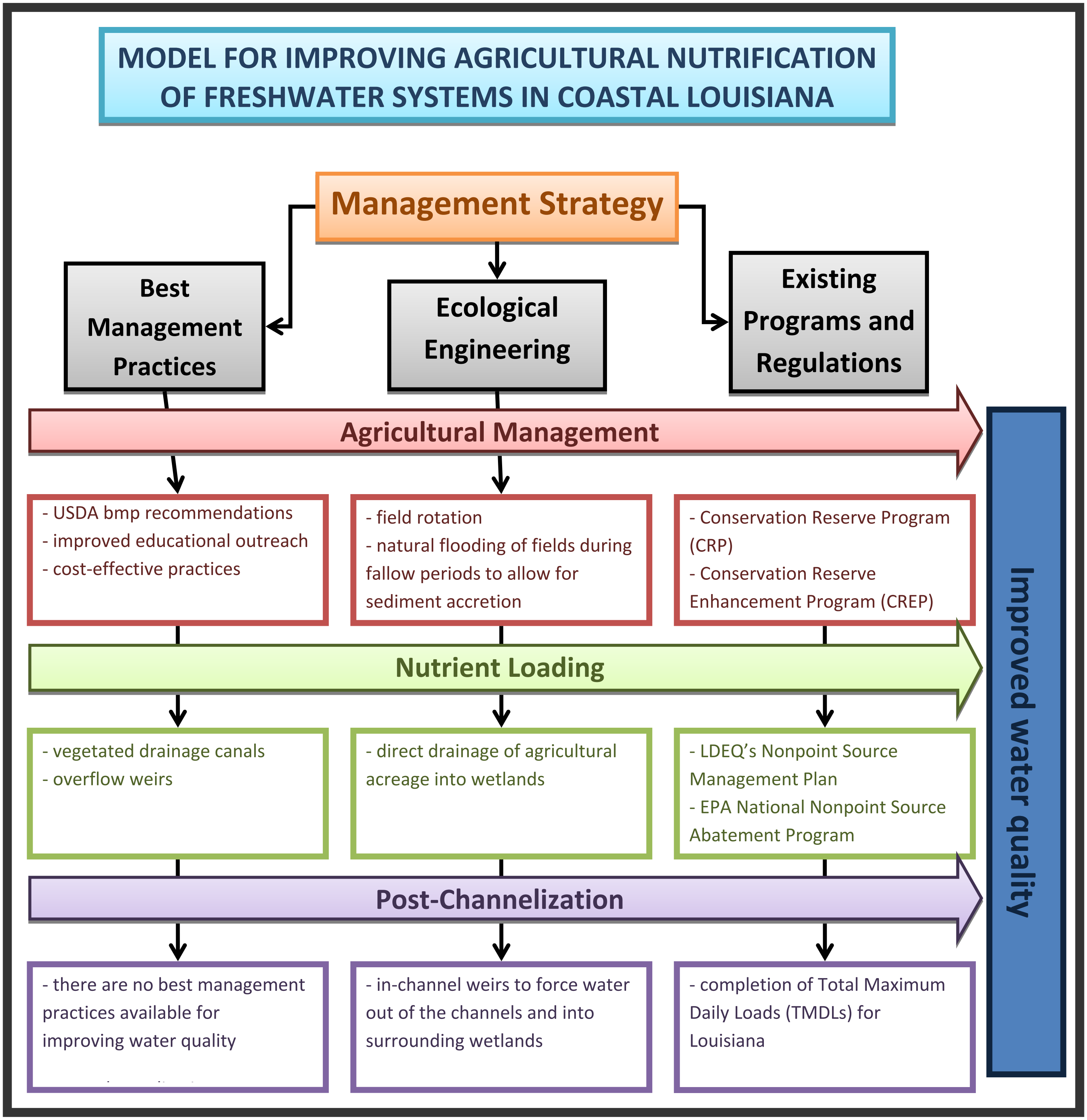

Figure 15: Proposed protocol BMP model for improved water quality in freshwater lakes.

cost-effective and improving educational programs, landowners will be more apt to adopt bmp practices. Best management practices are also available for implementation during the nutrient loading phase. In order to reduce the concentration of nutrients reaching the drainage ditches, vegetated drainage and overflow weirs should be used.

Ecological engineering techniques for improving water quality are available throughout the three management phases. During the agricultural management phase, landowners can rotate field usage and flood the fallow fields with river water providing the land with increased sediment and nutrient accretion. In order to prevent nutrification of a targeted water body, landowners can redirect agricultural drainage to flow through nearby wetlands instead of allowing for channelization. When large rain events occur, prevention of channelization may be difficult. By placing weirs in the affected channels, water can be pushed out of the channel and into the surrounding marsh.

Both the Conservation Reserve Program (CRP) and Conservation Reserve Enhancement Program (CREP), offered through the U.S. Department of Agriculture, are voluntary programs designed to aid farmers with natural resource concerns. These programs stress the need for best management practices that result in lower nutrient loss from agricultural lands. Louisiana landowners should consider participating in these two programs during the agricultural management phase of the proposed model. LDEQ continues to set water quality standards under their NPS Management Plan and applies annually for 319 grants. With set standards and funding, Louisiana can address nutrient loadings from agricultural runoff in coastal freshwater lakes. However, total maximum daily loads (TMDLs) are still needed in some locations in Louisiana. Without a set standard for designate usage, there exists no state goal for landowners to work towards.

By following the recommendations outlined in Figure 5.1, the Boeuf Basin and similar watersheds within Louisiana's coastal zone can achieve improved water quality. The model presents a three-tiered process that employs best management practices, ecological engineering principals, and current programs and regulations over three phases; agricultural management, nutrient loading, and post-channelization. This comprehensive plan can be utilized by Louisiana's agricultural managers at low cost and with the aid of federal and state programs. In order to spur adoption of this model, agencies are encouraged to offer financial incentives to those landowners who demonstrate continued progress in following with the model. Implementation will result in both improved water quality and sustainable agricultural acreage.

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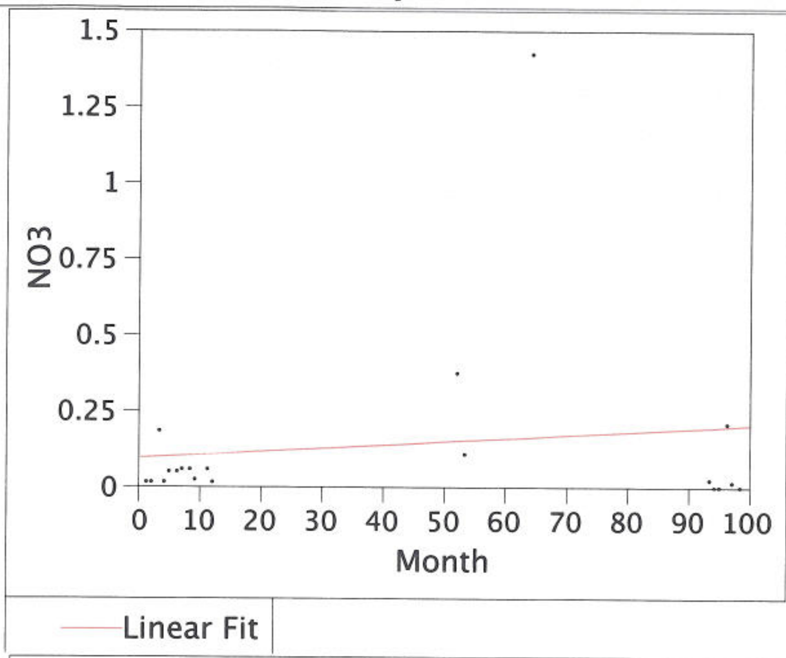
APPENDIX

6: Fit Y by X

Bivariate Fit of NO3 By Month



Linear Fit

NO3 = 0.095273 + 0.0010784 Month

Summary of Fit

RSquare	0.019478
RSquare Adj	-0.035
Root Mean Square Error	0.323089
Mean of Response	0.13895
Observations (or Sum Wgts)	20

Analysis of Variance

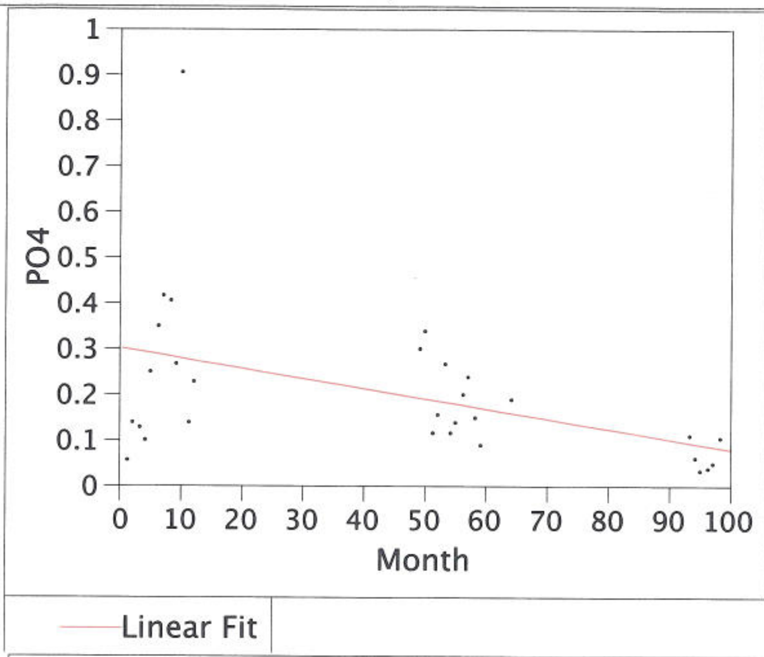
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	0.0373255	0.037325	0.3576
Error	18	1.8789535	0.104386	**Prob > F**
C. Total	19	1.9162790		0.5573

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	0.095273	0.102735	0.93	0.3660
Month	0.0010784	0.001804	0.60	0.5573

6: Fit Y by X

Bivariate Fit of PO4 By Month



Linear Fit

PO4 = 0.3013277 - 0.0022145 Month

Summary of Fit

RSquare	0.200209
RSquare Adj	0.171645
Root Mean Square Error	0.155491
Mean of Response	0.2047
Observations (or Sum Wgts)	30

Analysis of Variance

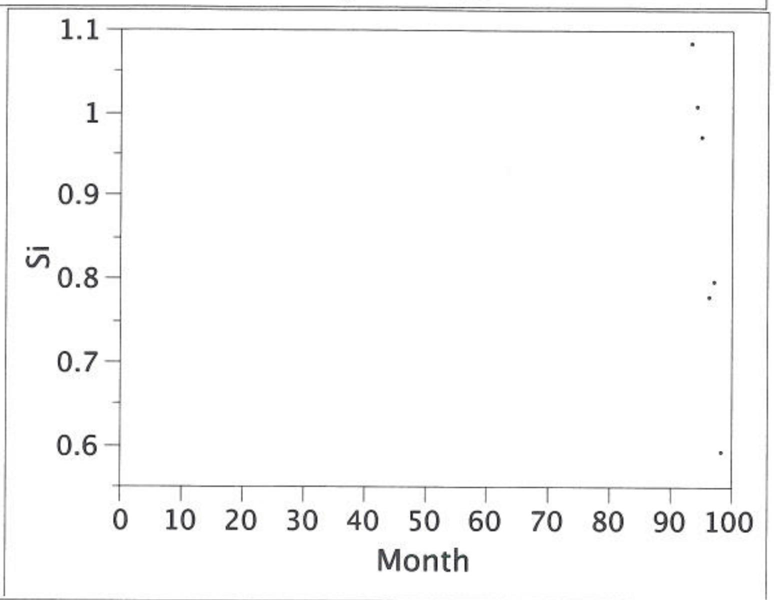
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	0.16946379	0.169464	7.0091
Error	28	0.67697051	0.024178	**Prob > F**
C. Total	29	0.84643430		0.0132

Parameter Estimates

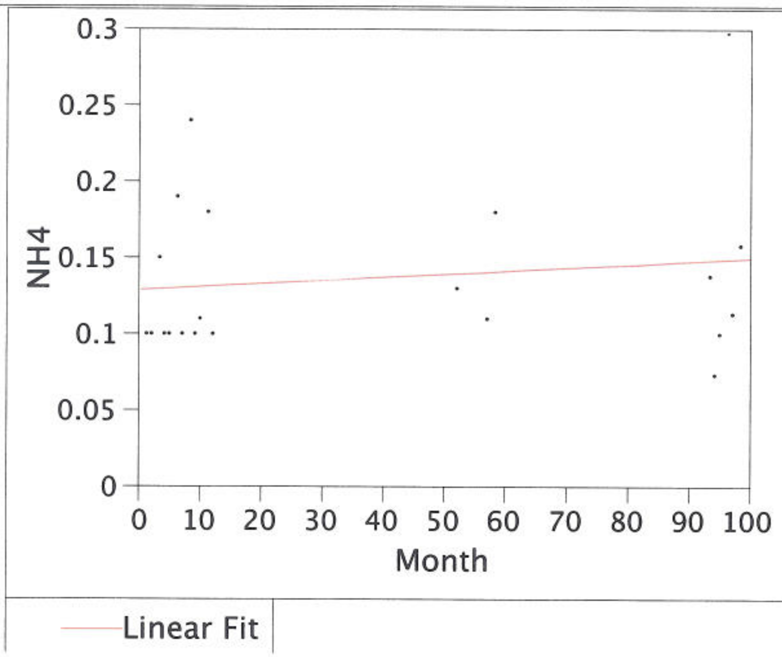
Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	0.3013277	0.046239	6.52	<.0001
Month	-0.002215	0.000836	-2.65	0.0132

6: Fit Y by X

Bivariate Fit of Si By Month



Bivariate Fit of NH4 By Month



6: Fit Y by X

Bivariate Fit of NH4 By Month

Linear Fit

NH4 = 0.1288223 + 0.0002087 Month

Summary of Fit

RSquare	0.023493
RSquare Adj	-0.0279
Root Mean Square Error	0.055946
Mean of Response	0.136952
Observations (or Sum Wgts)	21

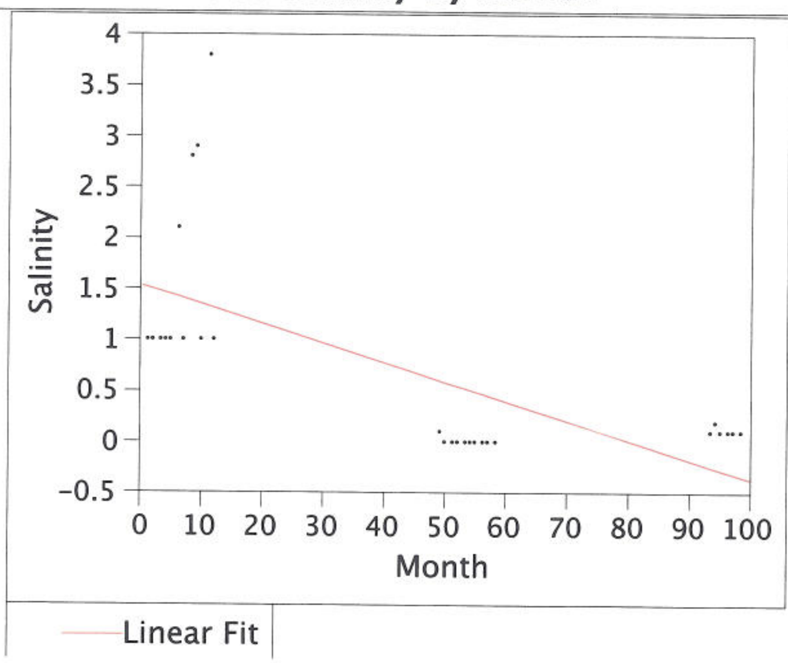
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	0.00143076	0.001431	0.4571
Error	19	0.05947019	0.003130	**Prob > F**
C. Total	20	0.06090095		0.5071

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	0.1288223	0.017136	7.52	<.0001
Month	0.0002087	0.000309	0.68	0.5071

Bivariate Fit of Salinity By Month



6: Fit Y by X

Bivariate Fit of Salinity By Month

Linear Fit

Salinity = 1.5362039 - 0.0190672 Month

Summary of Fit

RSquare	0.434395
RSquare Adj	0.412641
Root Mean Square Error	0.785141
Mean of Response	0.728571
Observations (or Sum Wgts)	28

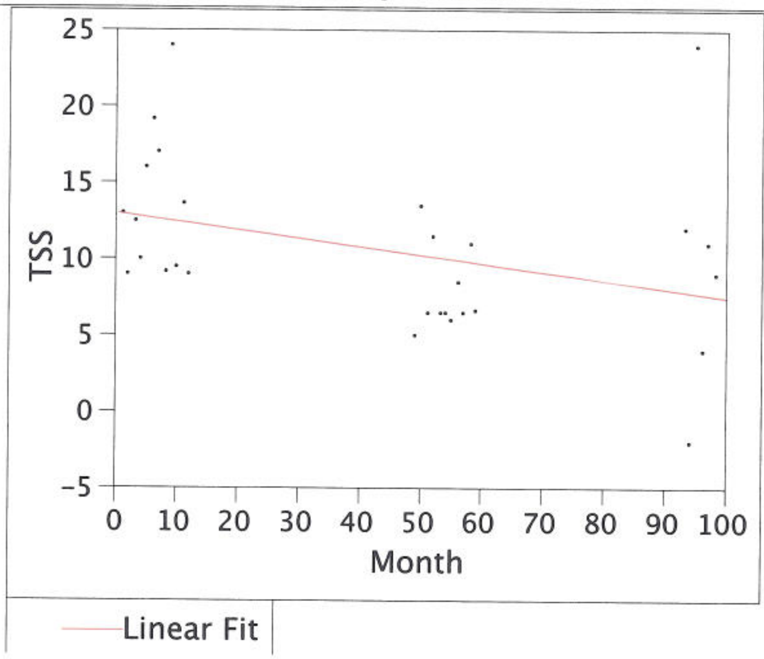
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	12.309517	12.3095	19.9685
Error	26	16.027625	0.6164	**Prob > F**
C. Total	27	28.337143		0.0001

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1.5362039	0.23384	6.57	<.0001
Month	-0.019067	0.004267	-4.47	0.0001

Bivariate Fit of TSS By Month



6: Fit Y by X

Bivariate Fit of TSS By Month

Linear Fit

TSS = 13.003795 - 0.0551085 Month

Summary of Fit

RSquare	0.116964
RSquare Adj	0.084259
Root Mean Square Error	5.383204
Mean of Response	10.63793
Observations (or Sum Wgts)	29

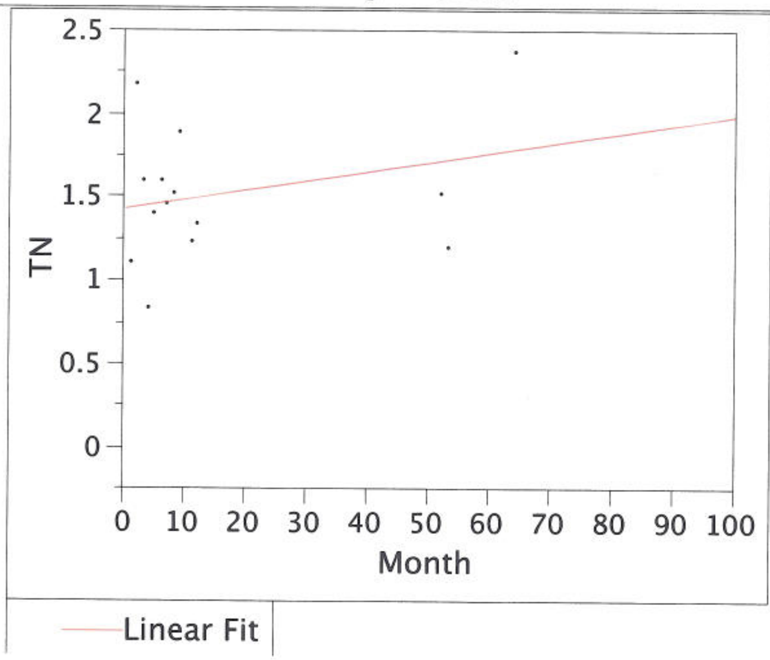
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	103.63832	103.638	3.5763
Error	27	782.42995	28.979	**Prob > F**
C. Total	28	886.06828		0.0694

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	13.003795	1.601364	8.12	<.0001
Month	-0.055108	0.029141	-1.89	0.0694

Bivariate Fit of TN By Month



6: Fit Y by X

Bivariate Fit of TN By Month

Linear Fit

TN = 1.4268802 + 0.0055851 Month

Summary of Fit

RSquare	0.08719
RSquare Adj	0.011122
Root Mean Square Error	0.409005
Mean of Response	1.521429
Observations (or Sum Wgts)	14

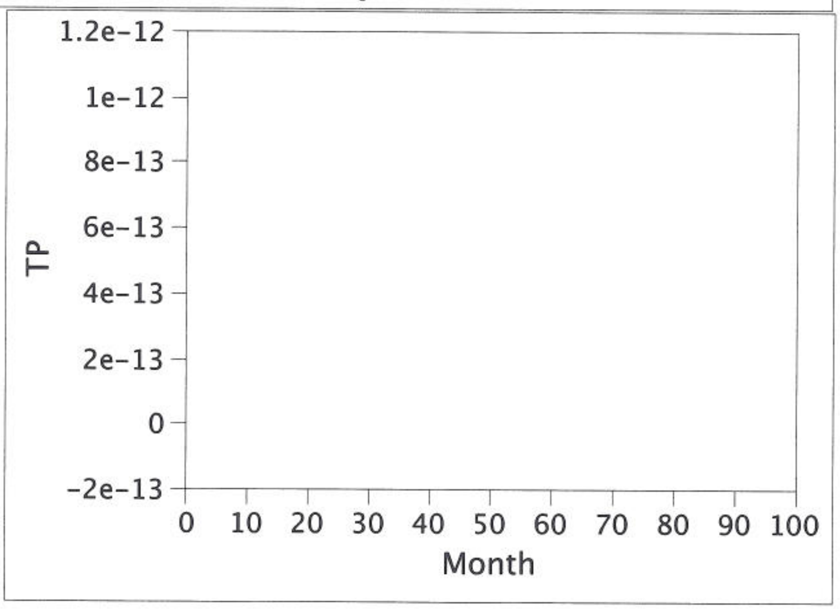
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	0.1917457	0.191746	1.1462
Error	12	2.0074258	0.167285	**Prob > F**
C. Total	13	2.1991714		0.3054

Parameter Estimates

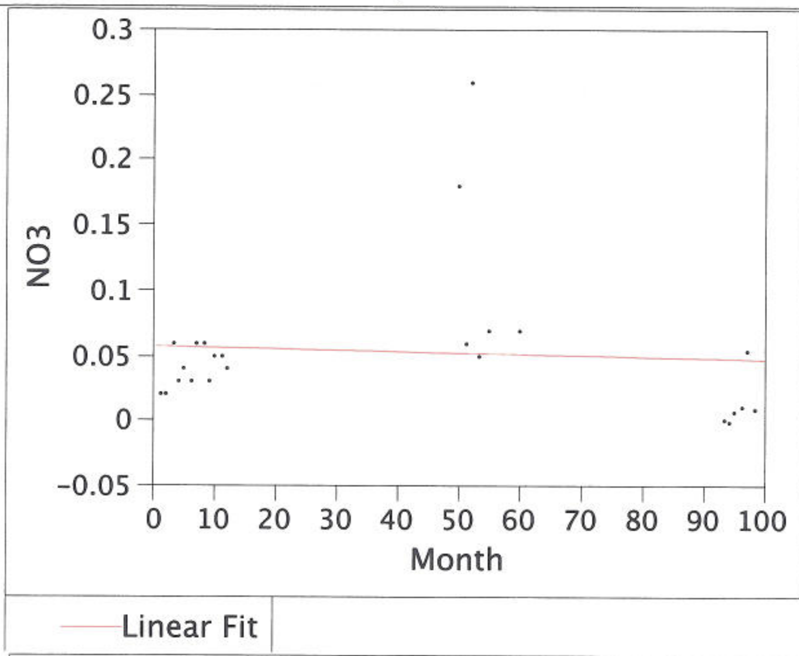
Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1.4268802	0.140528	10.15	<.0001
Month	0.0055851	0.005217	1.07	0.3054

Bivariate Fit of TP By Month



7: Fit Y by X

Bivariate Fit of NO3 By Month



Linear Fit

NO3 = 0.0567456 - 0.0001007 Month

Summary of Fit

RSquare	0.004498
RSquare Adj	-0.04075
Root Mean Square Error	0.058262
Mean of Response	0.052667
Observations (or Sum Wgts)	24

Analysis of Variance

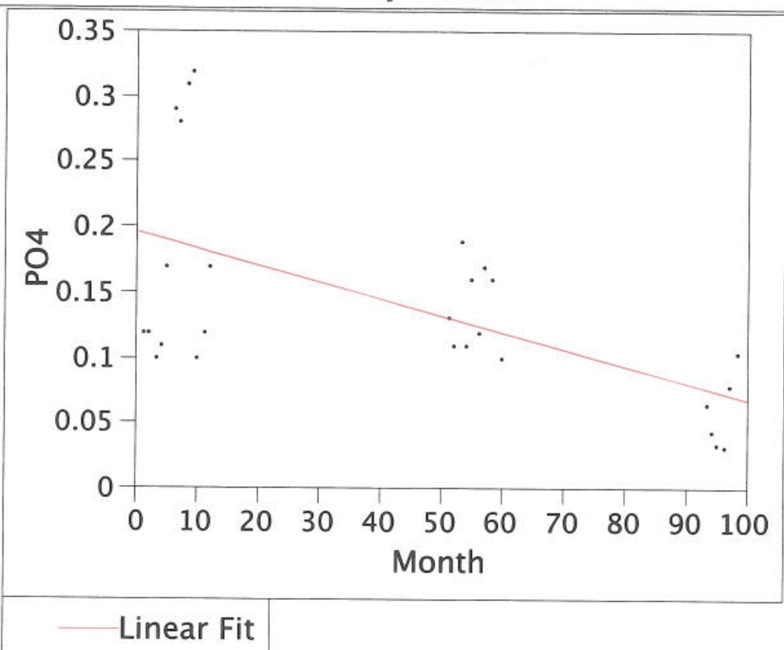
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	0.00033740	0.000337	0.0994
Error	22	0.07467794	0.003394	**Prob > F**
C. Total	23	0.07501533		0.7555

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	0.0567456	0.017573	3.23	0.0039
Month	-0.000101	0.000319	-0.32	0.7555

7: Fit Y by X

Bivariate Fit of PO4 By Month



Linear Fit

PO4 = 0.1958853 - 0.0012841 Month

Summary of Fit

RSquare	0.347828
RSquare Adj	0.321741
Root Mean Square Error	0.064909
Mean of Response	0.141333
Observations (or Sum Wgts)	27

Analysis of Variance

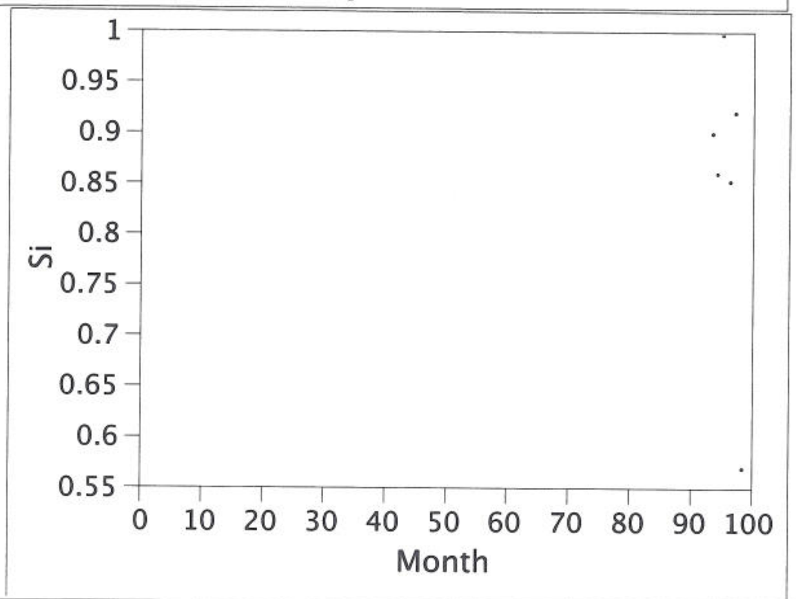
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	0.05617625	0.056176	13.3334
Error	25	0.10532975	0.004213	**Prob > F**
C. Total	26	0.16150600		0.0012

Parameter Estimates

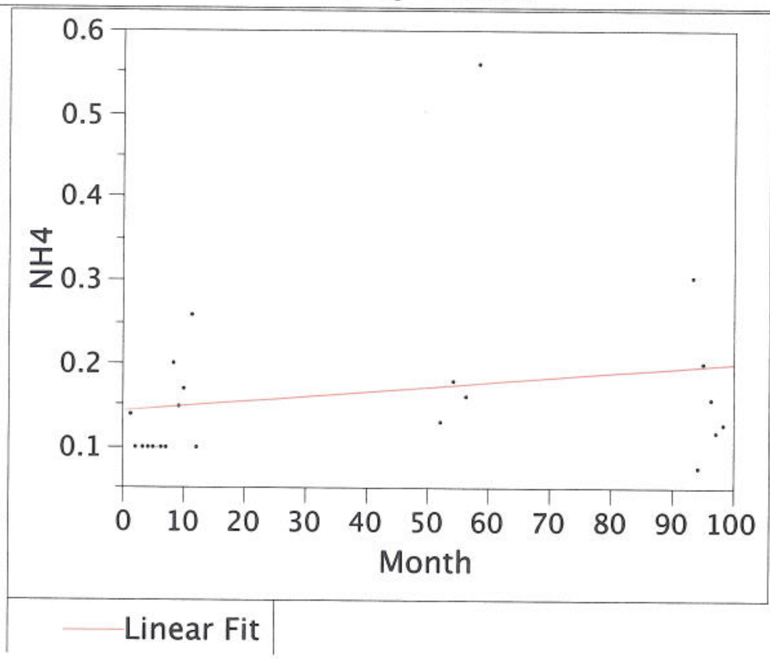
Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	0.1958853	0.019474	10.06	<.0001
Month	-0.001284	0.000352	-3.65	0.0012

7: Fit Y by X

Bivariate Fit of Si By Month



Bivariate Fit of NH4 By Month



7: Fit Y by X

Bivariate Fit of NH4 By Month

Linear Fit

NH4 = 0.1422653 + 0.0005754 Month

Summary of Fit

RSquare	0.047516
RSquare Adj	-0.00011
Root Mean Square Error	0.104684
Mean of Response	0.165045
Observations (or Sum Wgts)	22

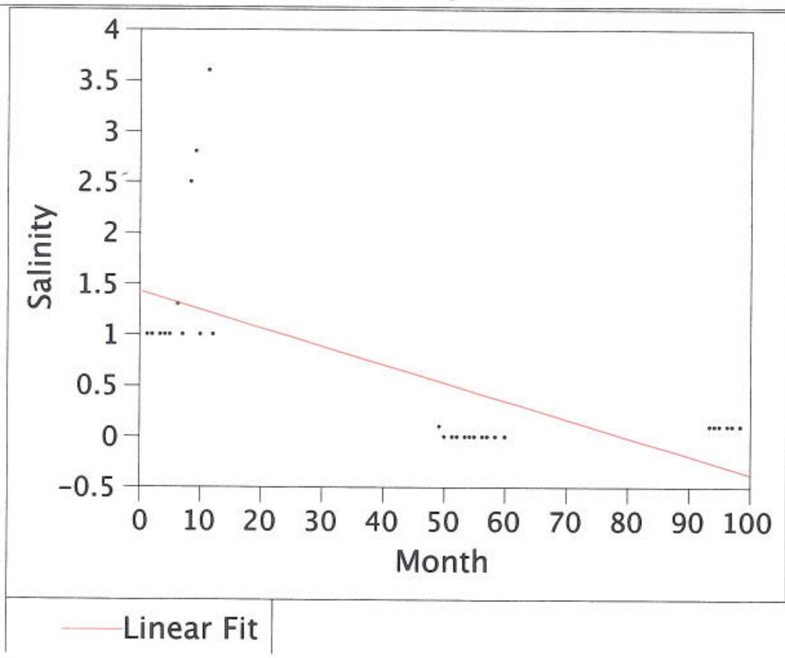
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	0.01093378	0.010934	0.9977
Error	20	0.21917317	0.010959	Prob > F
C. Total	21	0.23010695		0.3298

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	0.1422653	0.03191	4.46	0.0002
Month	0.0005754	0.000576	1.00	0.3298

Bivariate Fit of Salinity By Month



7: Fit Y by X

Bivariate Fit of Salinity By Month

Linear Fit

Salinity = 1.4230745 - 0.0179528 Month

Summary of Fit

RSquare	0.449507
RSquare Adj	0.429118
Root Mean Square Error	0.706659
Mean of Response	0.651724
Observations (or Sum Wgts)	29

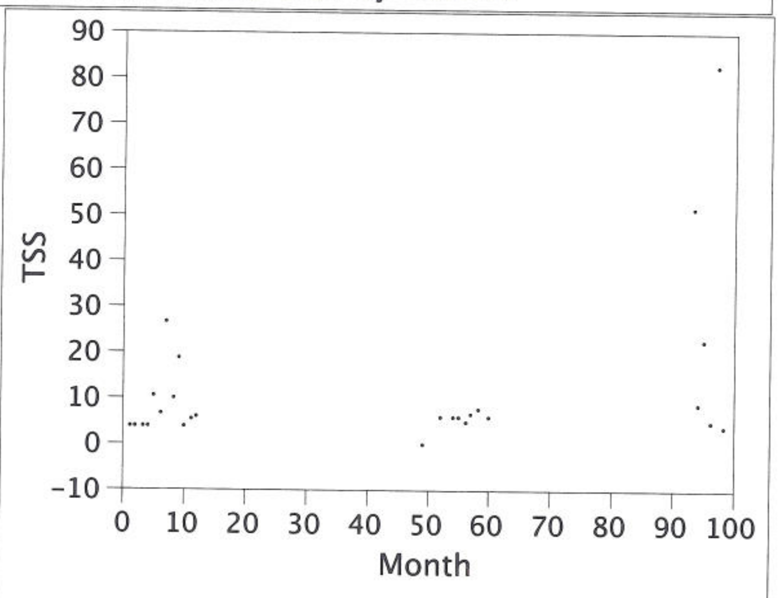
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	11.009509	11.0095	22.0469
Error	27	13.482905	0.4994	Prob > F
C. Total	28	24.492414		<.0001

Parameter Estimates

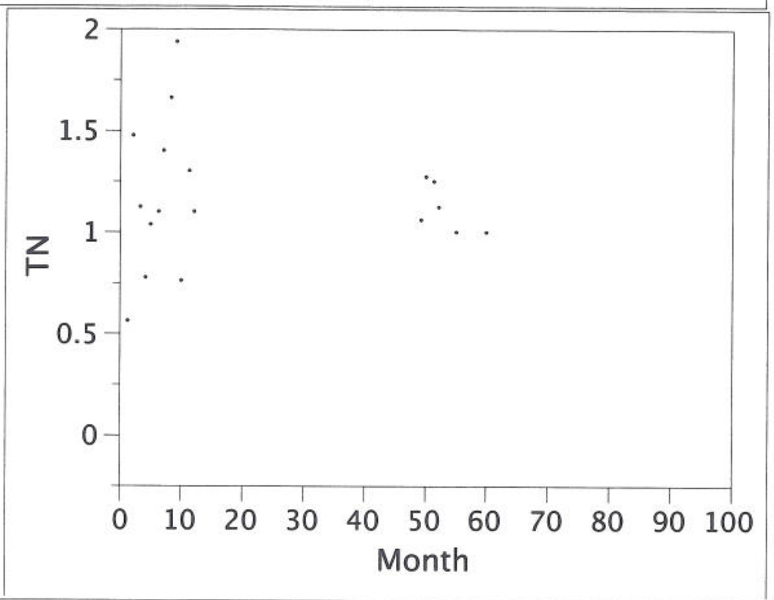
Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1.4230745	0.210254	6.77	<.0001
Month	-0.017953	0.003823	-4.70	<.0001

Bivariate Fit of TSS By Month

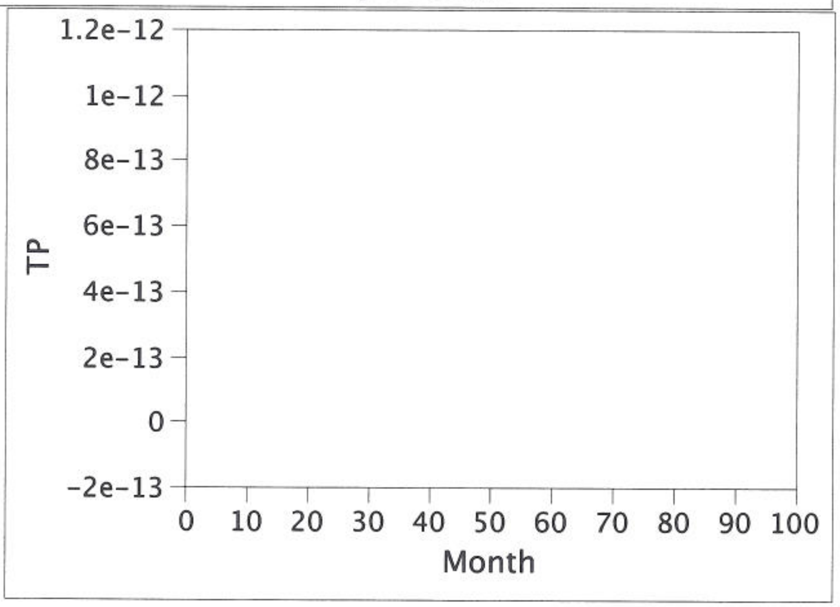


7: Fit Y by X

Bivariate Fit of TN By Month



Bivariate Fit of TP By Month



VITA

Joseph Wesley LeBlanc was born in Vestavia Hills, Alabama, U.S.A, in October 1979. Joseph moved to Baton Rouge, Louisiana in 1998 to pursue a bachelor's of science in Environmental Management Systems at Louisiana State University. After graduating in May of 2002, Joseph began working for the Louisiana Department of Natural Resources' Office of Coastal Restoration and Management in Baton Rouge. While continuing his employment, Joseph began work on his master's degree in Environmental Sciences in the fall of 2003.